ARIZONA DEPARTMENT OF WATER RESOURCES

AN APPLICATION OF THE REGIONAL GROUNDWATER FLOW MODEL OF THE SALT RIVER VALLEY, ARIZONA

ANALYSIS OF FUTURE WATER USE AND SUPPLY CONDITIONS: CURRENT TRENDS ALTERNATIVE 1989 - 2025

BY

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MODELING REPORT NO. 11

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EXECUTIVE SUMMARY

The Salt River Valley (SRV) groundwater flow model developed by the Arizona Department of Water Resources (ADWR) (Corkhill and others, 1993; Correl and Corkhill, 1994) was used to simulate groundwater conditions between 1988 and 2025. The simulation operated with assumptions of future water demands and supplies obtained in 1993 and 1994 from the principle water users and suppliers of the Salt River Valley and the staff of the Phoenix Active Management Area (AMA). This simulation is referred to as the Current Trends Alternative and will serve as a reference point against which other scenarios can be compared. This alternative is one of a number of alternative demand and supply scenarios that the Department will run to support its planning efforts that will enable the Phoenix AMA to meet the long term goal of safe yield for the area.

The Current Trends Alternative (CTA) represents the vision that the major water suppliers in the Phoenix AMA had in 1994 of the methods of supplying their future demands. The input from the cities and major irrigation districts was not always adjusted to meet the Department's concepts of how such future demands should be supplied. The CTA was developed in conjunction with Salt River Valley (SRV) water providers. Special attention was given to the West SRV, in a cooperative effort with the Westmarc group to conduct a hydrologic study called for by House Bill 2239, sponsered by Representative Jerry Overton. Partial funding for this study was provided by House Bill 2239 and by the US Bureau of Reclamation. The CTA is valuable in providing one view of a contrasting picture of future groundwater conditions. Another view of the picture will be water development and supply that meet the rules and regulations administered by the Department. The Assured Water Supply Program in particular will influence the future plans of the Department and the municipal water providers. These changes will need to be recognized in future alternative scenarios.

Key to the data analysis was the use of a Geographic Information System (GIS) to combine data from a variety of sources and areal extents. Using the GIS system the various forms of data were gathered for the common study areas referred to as Water Planning Areas (WPAs). The WPAs were determined by classifying the study area into regions of similar water supply and demand.

Population projections from the Maricopa Association of Governments (MAG) were used with a water use rate (gallons per household per day) to estimate the future municipal water demand.

Total groundwater demand was estimated by combining the projected municipal groundwater demand plus the projected agricultural demand. The total groundwater demand and estimated future recharge was used in the SRV groundwater flow model to evaluate the effects the projected stresses have on the groundwater system.

The results of the Current Trends Alternative scenario demonstrated the consequences of continuing to depend mostly on groundwater in the West Salt River Valley sub-basin (WSRV), where the projected depth to water by the year 2025 is up to 700 feet below land surface, assuming that the current reliance on groundwater continues. Declines of this magnitude could have major implications with regard to subsidence and degradation of groundwater quality, as well as causing an increase in the cost of withdrawing groundwater. In the East Salt River Valley (ESRV), except for an area in northern Scottsdale, the results were not as dramatic. This was largely due to the use current and projected increases in the use of renewable water sources and the presence of artificial recharge projects.

The CTA simulation provides a base point for future simulations to assist with the Third Management Plan, the Assured Water Supply program, and the planning efforts of the various municipalities and water providers within the Phoenix AMA. The SRV groundwater flow model is not intended to be a site specific indicator of water levels but is suitable for evaluating sub-basins and portions of sub-basins, and for evaluating the combined effects of many water users on the groundwater system. The model is a valuable tool in determining the relative effect of various scenarios concerning future water supply and demand within the Salt River Valley.

ACKNOWLEDGMENTS

The Arizona Department of Water Resources would like to acknowledge those individuals and organizations who contributed to the development and review of this report. The Department would also like to express its appreciation to the Bureau of Reclamation which provided partial funding of personnel costs associated with the study, and to Representative Jerry Overton, the sponsor of HB 2239, which authorized and funded work which contributed to this report. Overall project supervision was the responsibility of Frank Putman.

The Department would like to thank all those individuals, cities, towns, and irrigation districts which provided information for this study. In particular, appreciation is due the members of Westmarc's Water Resource Committee who worked closely with the Department on developing the assumptions for future water use and supply and in reviewing results. The Department also thanks past and present staff members Brad Hill, James Swanson, Frank Corkhill, Mark Frank, Monica Goy, Sandra Jaeger, David McNeil, and Terri Sue Rossi for their invaluable contributions during the various stages of this study.

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INTRODUCTION

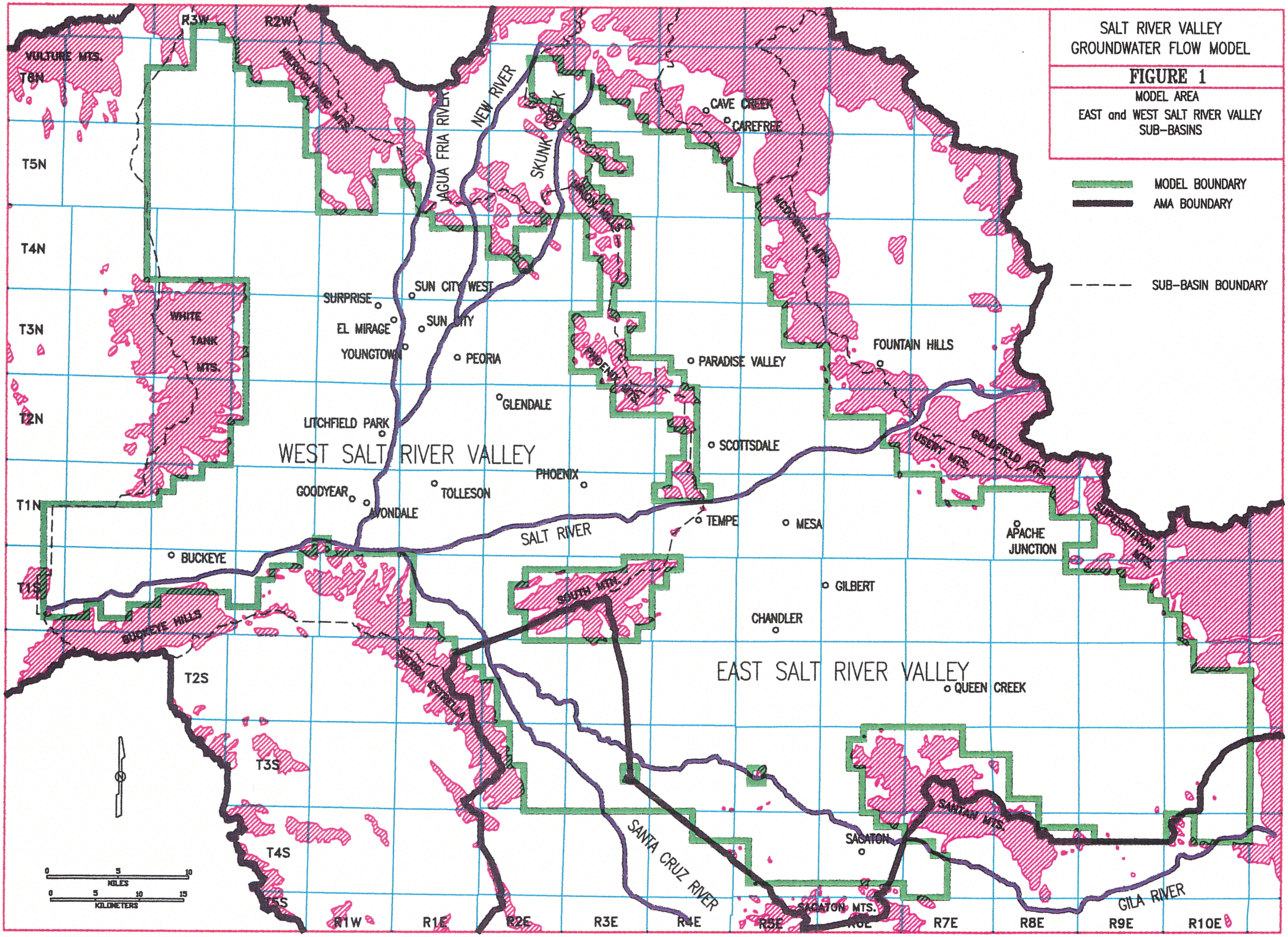
Overview

The U.S. Bureau of Reclamation (USBR) and the Arizona Department of Water Resources (ADWR) entered into a cooperative project to study current and future conditions of the groundwater system in the East and West Salt River Valley (SRV) sub-basins (Figure 1) in an effort to identify areas where undesirable groundwater conditions may exist in the future. Examples of such undesirable effects might be lowered water levels, land subsidence, continued depletion of groundwater reserves, and water quality degradation. The ultimate goal of the initial project was to develop methods of mitigating these undesirable effects by increasing the use of Central Arizona Project (CAP) water. The Department has continued the development and use of the model for many additional purposes, including technical assistance, long range planning, and education. This project was funded by the Department, the US Bureau of Reclamation and by HB 2239, which authorized the Department to continue working with West SRV water providers to analyze likely future water resources conditions. For this effort the Department worked closely with the Western Maricopa County Coalition (Westmarc) Water Resources Committee in developing future water use and supply scenarios.

This intergovernmental cooperative study had two major components. The first part identified water supply and water demands for 1991 through 2025 within the Phoenix AMA. The year 1991 was assumed to be representative of water use and supply patterns within the Phoenix metropolitan area. These data provided a basis for a projection of expected water supply and demand within the Phoenix AMA between 1995 to 2025. These projections used the 1991 estimates as a base year and took into account future supply and demand for both the Municipal and Industrial (M & I) and agriculture sectors within the East and West Salt River Valley sub-basins. A conceptual water budget for the future was constructed by working extensively with the municipalities, irrigation districts, and water supply companies. The conceptual water budget plays a critical part in accurately modeling future stresses on the groundwater system.

The second portion of this study utilized a numerical model of the Salt River Valley previously developed by ADWR (Correl and Corkhill, 1994; Corkhill and others, 1993) to simulate hydrologic conditions into the future to the year 2025. The location of model boundaries along with other features is depicted on Figure 1. The model projections identified areas of the groundwater system that may develop one or more of the undesirable effects previously mentioned. This "Current Trends Alternative" (CTA) model run evaluates the projected effects on the groundwater system of the future water demand and supply projections for the period 1995 to 2025. The projected demand and supply information was gathered from water users and suppliers in the Salt River Valley as well as from ADWR planning staff.

The Current Trends Alternative model simulation will serve as a reference point against which other management scenarios can be compared, thus providing guidance to water managers on the most useful management action. It should be noted that ADWR does not agree with all assumptions made for the CTA scenario, however, there is considerable value in projecting groundwater conditions based on the supply sources envisioned by the major water users in the Salt River Valley. The model results provided a visual representation of groundwater conditions resulting from current trends in municipal supply plans and existing agricultural practices. A contrasting scenario is currently being developed by the Department which fully recognizes the influence of the Assured Water Supply Rules amd water supply efforts on the development of future renewable supplies. A comparison between the two scenarios will serve to help evaluate the effectiveness of the AWS and recharge programs in meeting the Department's goal of safe yield for the Phoenix AMA.


SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE 1
MODEL AREA
EAST and WEST SALT RIVER VALLEY
SUB-BASINS
MODEL BOUNDARY
AMA BOUNDARY
SUB-BASIN BOUNDARY
WEST SALT RIVER VALLEY
EAST SALT RIVER VALLEY
VULTURE MTS.
HIEROGLYPHIC MTS.
WHITE TANK MTS.
BUCKEYE HILLS
SIERRA ESTRELLA
SOUTH MTN.
PHOENIX MTS.
MCDOWELL MTS.
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
SANTAN MTS.
SACATON MTS.
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
SALT RIVER
SANTA CRUZ RIVER
GILA RIVER
CAVE CREEK
CAREFREE
SURPRISE
SUN CITY WEST
SUN CITY
EL MIRAGE
YOUNGTOWN
PEORIA
GLENDALE
LITCHFIELD PARK
GOODYEAR
AVONDALE
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PHOENIX
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FOUNTAIN HILLS
TEMPE
MESA
GILBERT
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QUEEN CREEK
SACATON
BUCKEYE
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T1S
T2S
T3S
T4S
T5S
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R7E
R8E
R9E
R10E
MILES
KILOMETERS
0
5
10
15

Purpose and Scope

The purpose of this study was to use a numerical model developed by ADWR to simulate groundwater conditions in the Salt River Valley and identify areas of concern between the period 1995 to 2025. The CTA model run will serve as a basis with which to compare alternative future water demand and uses scenarios within the Phoenix AMA.

The scope of the CTA model run was to evaluate the regional effects on the groundwater system from the estimates of future water demand (e.g., agricultural, municipal and industrial (M & I)) supply (e.g., groundwater, surface water, CAP water, effluent, and recharge) within the Phoenix AMA. Future demand and supply information utilized in the model is representative of what the principle water users and suppliers project, as of 1993 and 1994, will occur in the future. The data preparation and analysis for the Current Trends Alternative simulation was accomplished by utilizing a Geographic Information System (GIS) to analyze data from a variety of sources and to track demographic features such as population growth, M & I demand and agricultural demand into the future for specific planning areas. These areas were designed to delineate areas of different water supply or demand. The results of the GIS calculations were used in the SRV groundwater model with an emphasis on evaluating the effects the projected stresses have on the groundwater system.

Prior Studies

The Salt River Valley groundwater flow model was developed by ADWR over two phases. Phase I compiled and analyzed the basic hydrogeologic framework and data for the Salt River Valley (Corkhill and others, 1993). The predevelopment (circa 1900) hydrologic system was analyzed along with the modern system from 1978 to 1988. Phase I provided the background hydrological and geological information from which a MODFLOW groundwater flow model could be developed. Included within the Phase I report is a discussion of the methodologies used to compile and analyze groundwater recharge, pumpage, evapotranspiration, and underflow. The bulk of the information for the predevelopment groundwater conditions in the Salt River Valley were obtained from reports by Davis (1897, 1903), Lippincott (1900), and Lee (1904, 1905). These reports contained a wealth of information concerning the irrigation, surface and groundwater supplies, and the storage of water. The recent studies that contributed to the understanding of the modern hydrogeology of the area include groundwater maps produced by Ross (1978) and Reeter and Remick (1983) plus hydrogeological studies conducted by the United States Bureau of Reclamation (USBR, 1976), Laney and Hahn (1986), and Brown and Pool (1989).

The Phase II report documents the development of a MODFLOW groundwater flow model for the Salt River Valley simulating steady-state groundwater flow (circa 1900) and transient-state groundwater flow (1983 to 1988) (Corell and Corkhill, 1994). The model geologically simulates three geological layers/aquifers and hydraulically groundwater underflow, groundwater pumpage, seepage to and from perennial river reaches, and groundwater recharge from agricultural irrigation, major flood events and canals. The model was calibrated and reasonably simulated groundwater flow directions and water levels for both steady-state and transient-state groundwater flow conditions. Included in the report was a sensitivity analysis to determine how variations of the model input components effected the final model solution. Appendix I of this report expands on the details of the modeling effort.

HISTORIC and CURRENT GROUNDWATER CONDITIONS

The Salt River Valley (SRV) consists of two distinct but interconnected alluvial groundwater basins, the West Salt River Valley (WSRV) and the East Salt River Valley (ESRV). In the SRV groundwater flow model the primary focus is on the basin-fill deposits since they constitute the regional aquifer in the SRV. The basin-fill deposits consist of interbedded sequences of conglomerate, gravel, sand, silt, clay, and evaporites. These sediments were subdivided into three hydrogeologic units for modeling purposes, in ascending order: 1) Lower Alluvial Unit (LAU), 2) Middle Alluvial Unit (MAU), 3) Upper Alluvial Unit (UAU). The stratigraphic relationships among the three hydrogeologic units are presented in Figure 2. A more detailed discussion of the hydrogeology is provided in the SRV Phase I report (Corkhill and others, 1993). For simplicity only the MAU maps were used to represent groundwater conditions within the report, however, the UAU and LAU maps are provided in Appendix III.

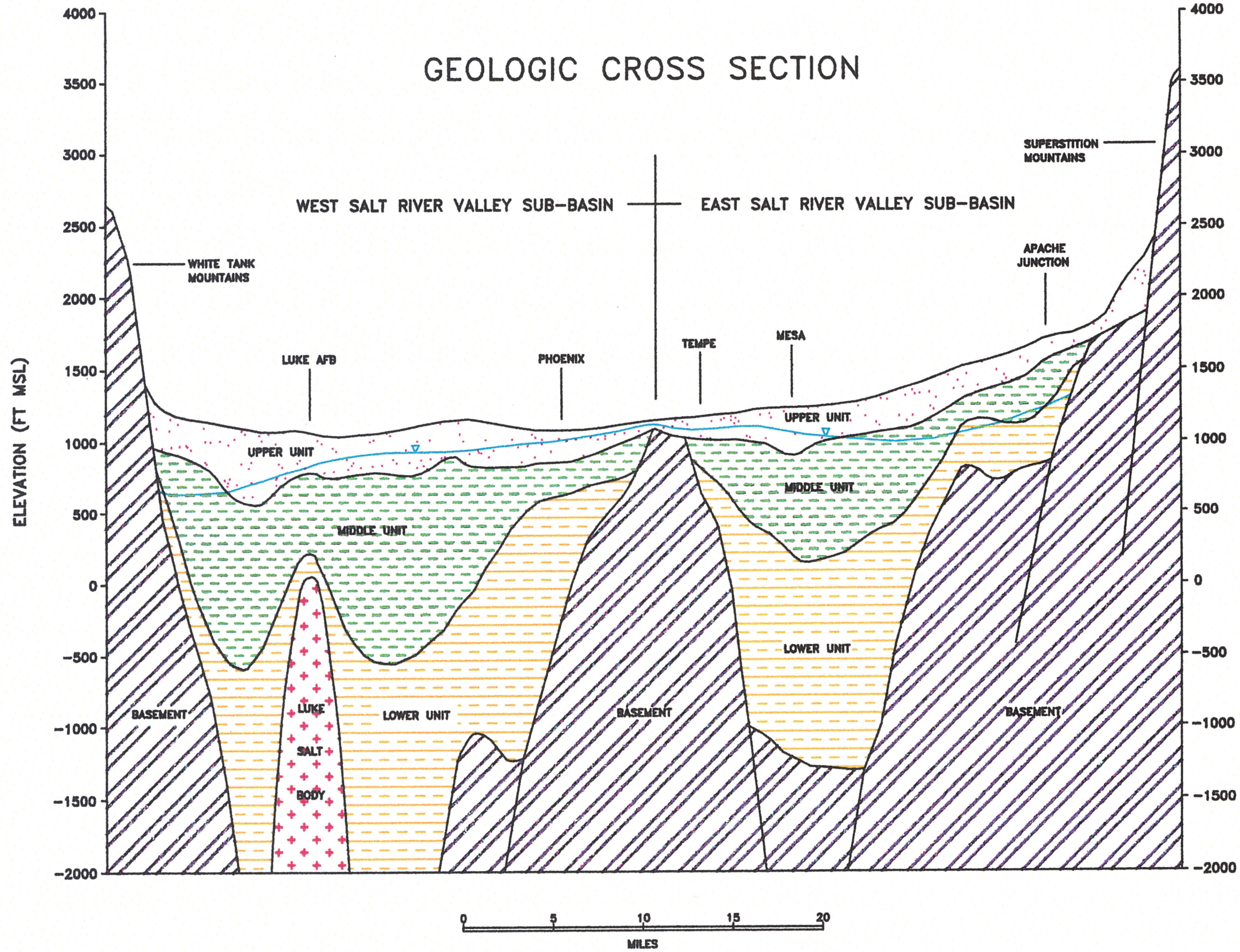
To better comprehend the modeling results a brief synopsis is presented of the current and historic groundwater conditions of the SRV. Historically, the groundwater condition of the Salt River Valley (SRV) has changed greatly as a result of agricultural activity and urbanization. In 1900, although irrigation was extensive in the area served by the Salt River Project and in the Buckeye area, pre-development groundwater conditions still existed in most of the Phoenix AMA. Groundwater in the SRV flowed generally from north to south and from east to west, eventually discharging to the Salt and Gila Rivers, which generally flowed year-round. Groundwater flow to the rivers had not yet been intercepted by extensive groundwater pumping.

Beginning in the 1940's groundwater pumping increased greatly as a result of the introduction of the turbine pump, which allowed efficient production of large volumes of groundwater for the cultivation of thousands of acres of new farmland. Groundwater levels fell hundreds of feet between 1900 and 1983 in some areas of the Salt River Valley as a result of almost 80 million acre-feet of groundwater withdrawal. In the West Salt River Valley (WSRV), groundwater level declines of more than 300 feet occurred in the area of Luke Air Force Base (Figure 3), and the land surface in some portions of the area has subsided by more than 18 feet by 1991 (Schumann, 1995).

FIGURE 2

PHOENIX ACTIVE MANAGEMENT AREA

EAST AND WEST SALT RIVER VALLEY SUB-BASINS



VERTICAL EXAGGERATION = 34.5 X

FROM: Arizona Department of Water Resources

D:\SRV\SRXAMA.dwg

In the ESRV declines of over 300 feet were noted near Paradise Valley and an area east of Mesa (Figure 3) The Paradise Valley area subsided 5 feet from 1965 to 1982 with subsidence rates of up to 35 feet per year (Schumann and Genualdi, 1986)

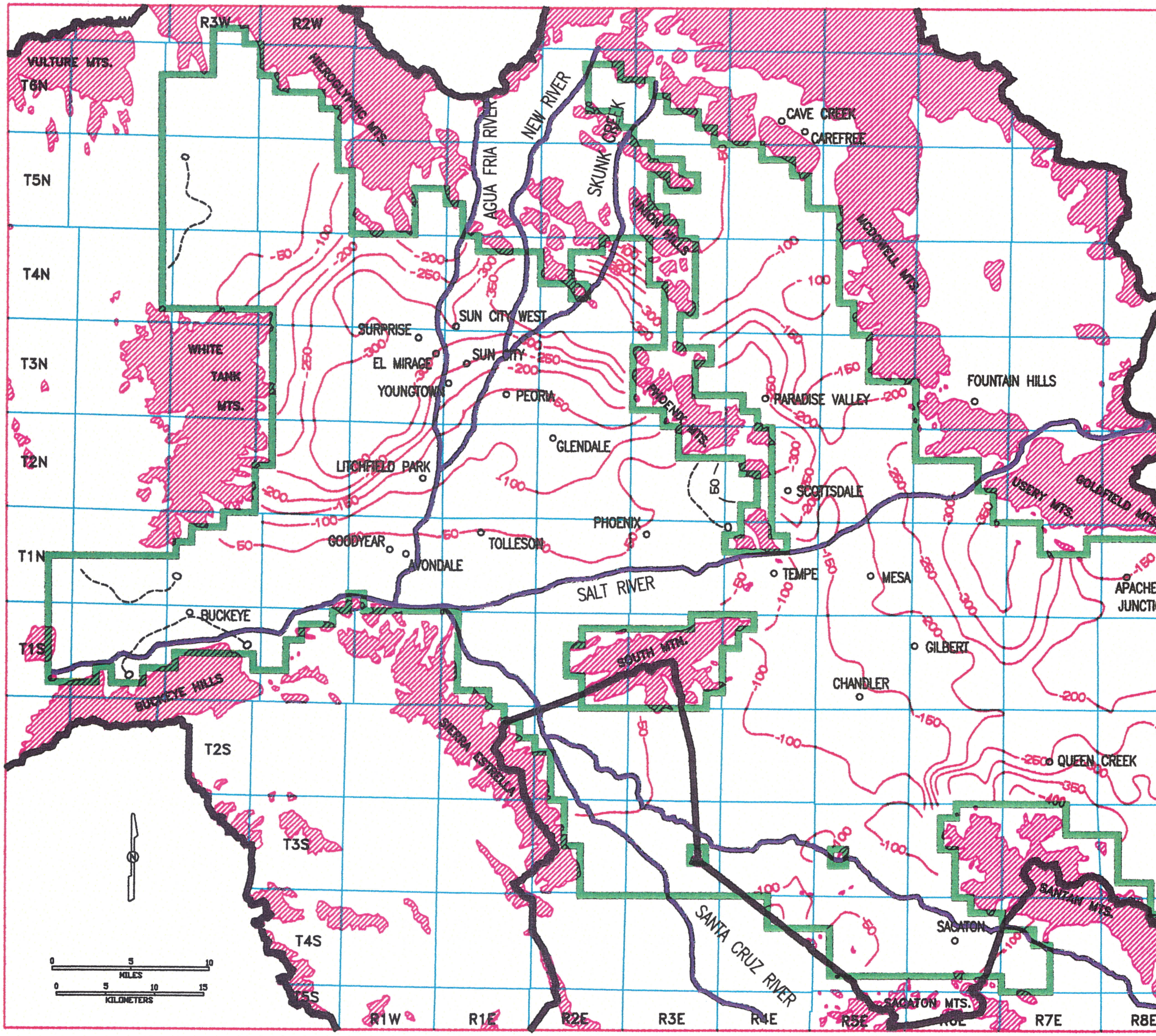
Between 1983 and 1991 water levels in the Phoenix AMA have stabilized or recovered slightly, with the exception of the areas around Peoria, Sun City, and north Scottsdale, which are dependant entirely on groundwater withdrawals (Figure 4) The recovery is due to several factors Among them are a general decline in agricultural pumpage while recharge from extensive irrigation in the 1970's is still reaching the aquifer During the last decade higher than average recharge along the rivers of the AMA has also occurred due to flooding, and increased surface water availability due to much wetter than normal conditions has reduced groundwater pumpage The Department's predictive hydrologic modeling, even taking these recent ground water level rises and higher than normal river recharge into account, shows further drawdowns for many areas in the WSRV in future years This projected decline is a reflection of the following assumptions surface water recharge from long term average flows (1964 to 1991), not the high levels of availability seen in the 1980's, reduced farming levels representative of the 1980's as compared to the 1970's, and a gradual reduction in agricultural recharge as a function of the farm economy, urbanization and the agricultural recharge "lag time" calculations

Current (1991) groundwater elevations and general flow directions are illustrated in Figure 6 Groundwater in most of the WSRV is currently flowing to a large cone of depression known as the Luke Sink The Luke Sink is centered south of Youngtown and was created primarily by agricultural pumping Water levels have declined over 300 feet from pre-development levels in this area (Schumann and Genualdi, 1986) Further to the south, groundwater flow continues to follow the path of the Gila River and leaves the WSRV at the site of Gillespie Dam (Figure 5) Much of the current groundwater flow in the ESRV is controlled by groundwater sinks located in the Paradise Valley area and east of Mesa, and in an area along the Santan Mountians (Figure 5) A small amount of underflow occurs in the Upper Alluvial Unit along the Salt River and in the Upper, Middle, and Lower Alluvial Units along the Gila River from the ESRV into the WSRV

SALT RIVER VALLEY
GROUNDWATER FLOW MODEL

FIGURE 3

WATER LEVEL CHANGES FROM 1900 TO 1983
MIDDLE ALLUVIAL UNIT



MODEL BOUNDARY

AMA BOUNDARY

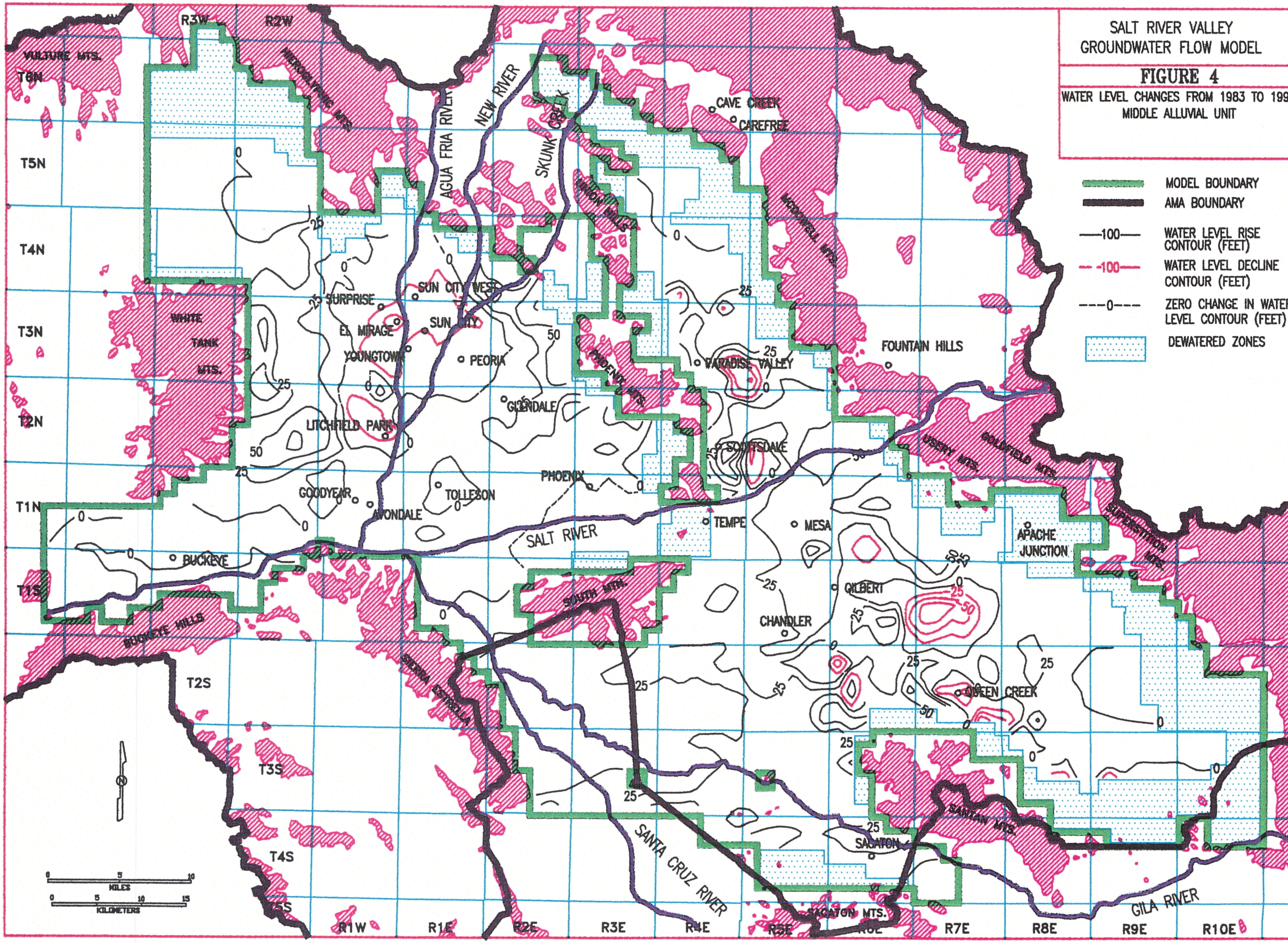
—100— WATER LEVEL RISE CONTOUR (FEET)

- -100- WATER LEVEL DECLINE CONTOUR (FEET)

---0--- ZERO CHANGE IN WATER LEVEL CONTOUR (FEET)

50 FOOT CONTOUR INTERVAL

DATA FROM ADWR – GWSI


SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE 4
WATER LEVEL CHANGES FROM 1983 TO 1991
MIDDLE ALLUVIAL UNIT
MODEL BOUNDARY
AMA BOUNDARY
—100— WATER LEVEL RISE CONTOUR (FEET)
-100- WATER LEVEL DECLINE CONTOUR (FEET)
---0--- ZERO CHANGE IN WATER LEVEL CONTOUR (FEET)
DEWATERED ZONES
VULTURE MTS.
HIEROGLYPHIC MTS.
WHITE TANK MTS.
BUCKEYE HILLS
SIERRA ESTRELLA
SOUTH MTN.
PHOENIX MTS.
UNION HILLS
MCDOWELL MTS.
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
SANTAN MTS.
SACATON MTS.
AGUA FRIA RIVER
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GLENDALE
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GOODYEAR
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PARADISE VALLEY
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TEMPE
MESA
GILBERT
CHANDLER
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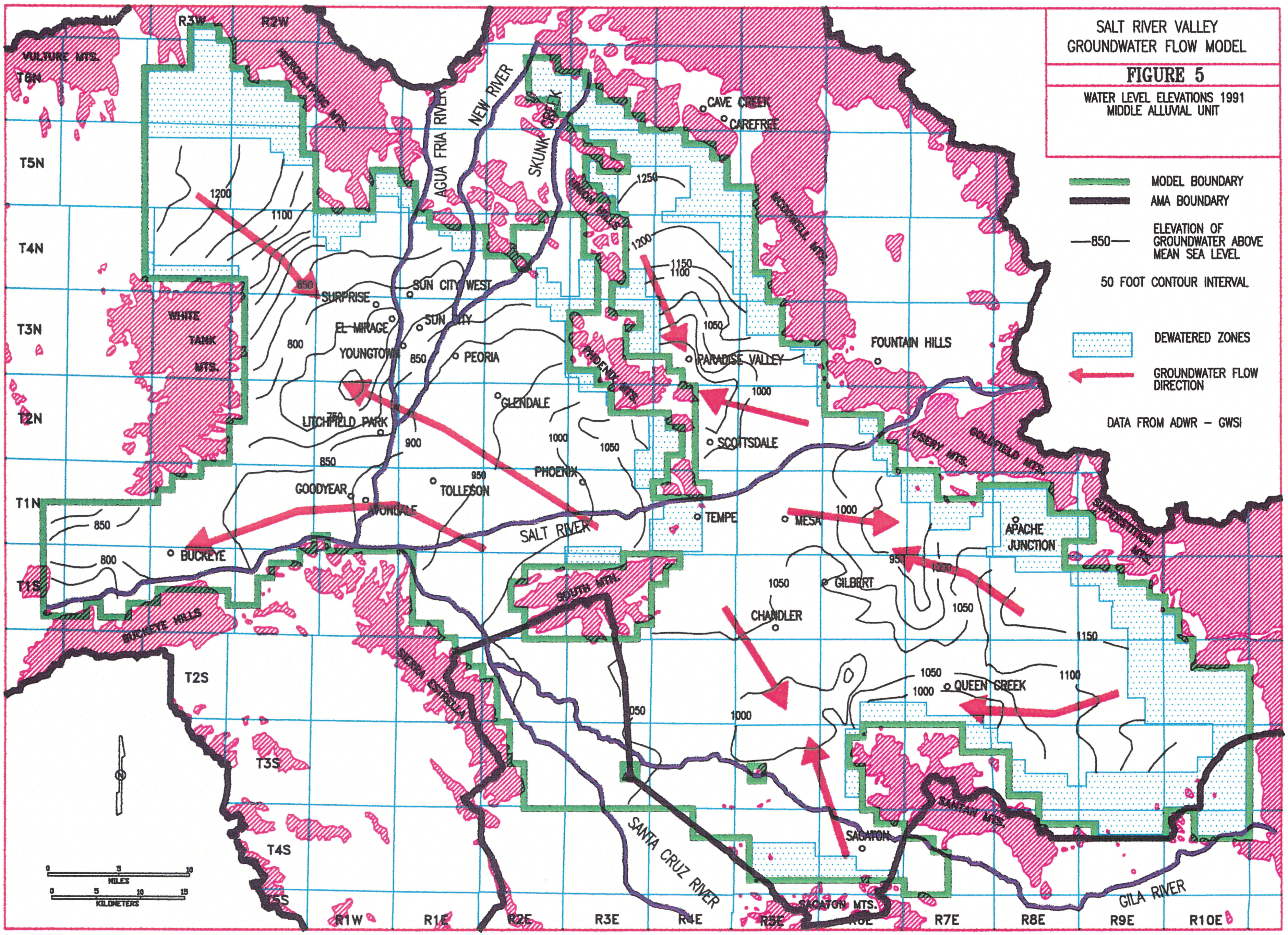
T1N
T1S
T2S
T3S
T4S
T5S
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R7E
R8E
R9E
R10E
MILES
KILOMETERS



SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE 5
WATER LEVEL ELEVATIONS 1991
MIDDLE ALLUVIAL UNIT
MODEL BOUNDARY
AMA BOUNDARY
—850— ELEVATION OF GROUNDWATER ABOVE MEAN SEA LEVEL
50 FOOT CONTOUR INTERVAL
DEWATERED ZONES
GROUNDWATER FLOW DIRECTION
DATA FROM ADWR – GWSI
VULTURE MTS.
HIEROGLYPHIC MTS.
WHITE TANK MTS.
CAVE CREEK
CAREFREE
MCDOWELL MTS.
FOUNTAIN HILLS
UNION HILLS
PHOENIX MTS.
PARADISE VALLEY
SCOTTSDALE
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
SUN CITY WEST
SUN CITY
SURPRISE
EL MIRAGE
YOUNGTOWN
PEORIA
GLENDALE
LITCHFIELD PARK
GOODYEAR
AVONDALE
TOLLESON
PHOENIX
TEMPE
MESA
SALT RIVER
BUCKEYE
BUCKEYE HILLS
SOUTH MTS.
SIERRA ESTRELLA
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
APACHE JUNCTION
GILBERT
CHANDLER
QUEEN CREEK
SACATON
SACATON MTS.
SANTAN MTS.
SANTA CRUZ RIVER
GILA RIVER
T6N
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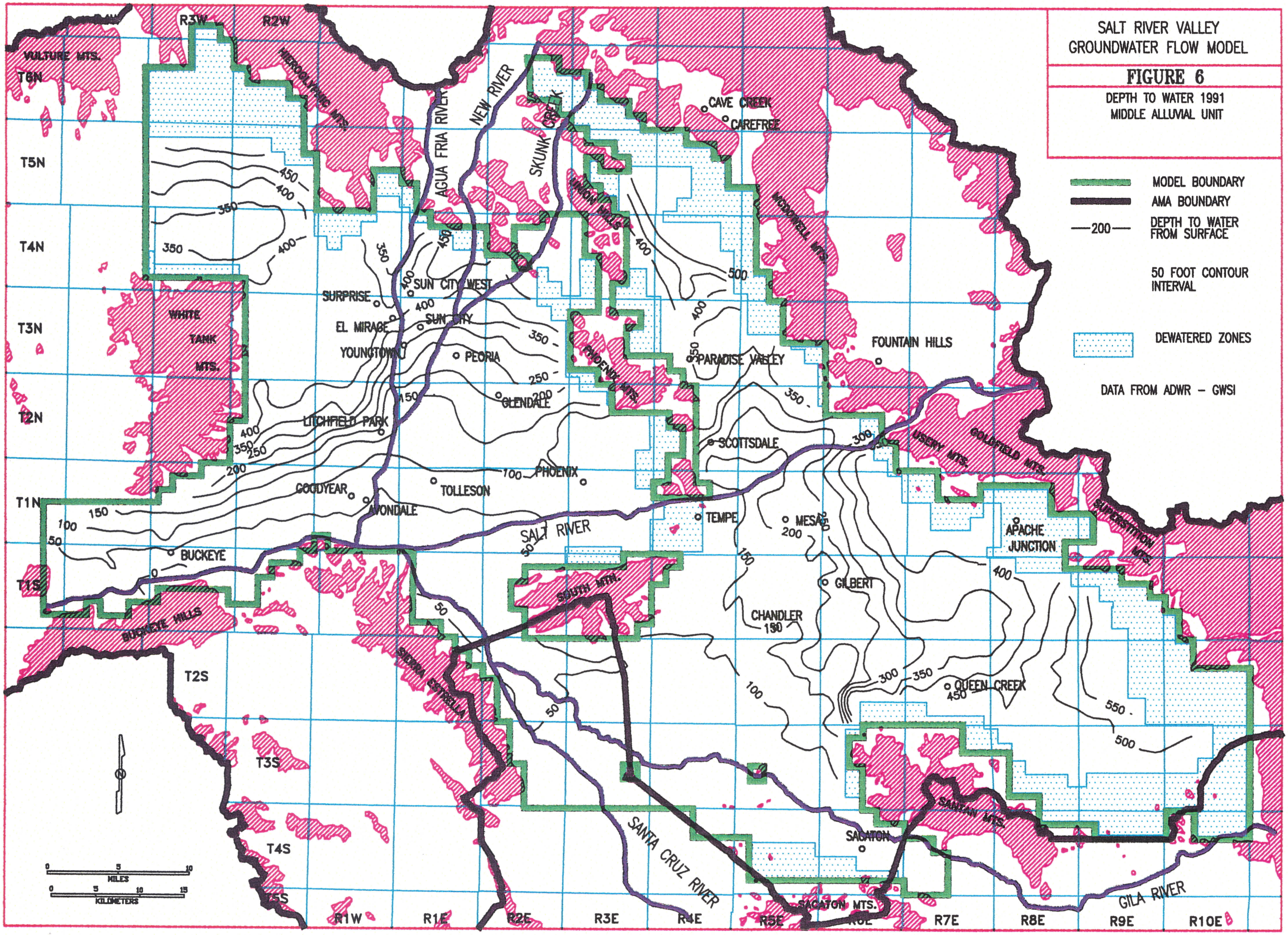
T4N
T3N
T2N
T1N
T1S
T2S
T3S
T4S
T5S
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R6E
R7E
R8E
R9E
R10E
MILES
KILOMETERS

The 1991 Depth to Water map (Figure 6) is useful in determining areas that may have Assured Water Supply problems, waterlogging problems, and increased costs for drilling water wells. The current areas of high depths-to-water, in the northern parts of the SRV, are areas that are projected to have physical availability problems under the CTA scenario. The area near Buckeye (Figure 6) is waterlogged and drainage wells are needed to keep groundwater levels low enough to avoid crop damage. Water logging began to occur most recently in the 1960's when the 91st Avenue waste water treatment plant (WWTP) expanded and effluent releases began to recharge the groundwater system.


SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE 6
DEPTH TO WATER 1991
MIDDLE ALLUVIAL UNIT
MODEL BOUNDARY
AMA BOUNDARY
—200— DEPTH TO WATER FROM SURFACE
50 FOOT CONTOUR INTERVAL
DEWATERED ZONES
DATA FROM ADWR - GWSI
VULTURE MTS.
HIEROGLYPHIC MTS.
WHITE TANK MTS.
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
CAVE CREEK
CAREFREE
MCDOWELL MTS.
FOUNTAIN HILLS
PARADISE VALLEY
SCOTTSDALE
PHOENIX MTS.
SURPRISE
SUN CITY WEST
SUN CITY
EL MIRAGE
YOUNGTOWN
PEORIA
GLENDALE
LITCHFIELD PARK
GOODYEAR
AVONDALE
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SALT RIVER
TEMPE
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CHANDLER
APACHE JUNCTION
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SOUTH MTN.
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SANTA CRUZ RIVER
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SAN TAN MTS.
GILA RIVER
T6N
T5N
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T3N
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T3S
T4S
T5S
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R7E
R8E
R9E
R10E
MILES
KILOMETERS

CONCEPTUAL WATER BUDGET and PROJECT

The purpose of a conceptual water budget is to understand and simplify the groundwater system. Generally it is desirable to simplify the conceptual water budget as much as possible while still retaining the complexity needed to adequately reproduce the behavior of the groundwater system. Building a conceptual water budget also organizes the associated data so the hydrologic system can be analyzed more readily. The conceptual water budget for this study include underflow (groundwater inflow and outflow), natural recharge (river and mountain front recharge), artificial recharge (agricultural irrigation, urban irrigation, canals, effluent, recharge projects, artificial lakes), pumpage, and evapotranspiration (Table 1).

The variables in the inflow portion of the conceptual water budget were split into underflow, ephemeral stream infiltration and underflow, and recharge. The underflow and the ephemeral stream infiltration and underflow were determined from historic averages to simulate these variables for the period 1992 to 2025. The recharge portion of the inflow was calculated from a combination of historic averages and calculations based on declining agriculture due to population growth. The methods for determining these numbers will be discussed in more detail.

The major variables in the out flows of the groundwater system include underflow out of the model, evapotranspiration, and pumpage. The underflow out of the model and evapotranspiration were projected to remain constant for the model period. The decrease in pumpage values from 1991 to 1995 is a result of a historic trend of decreasing agricultural pumping. The increase in pumpage from 1995 to 2025 reflects an increase in population, as predicted by the Maricopa Association of Governments (MAG), 1993, and related water demands. Each water budget component in Table 1 is fully discussed later in this section.

Inflow

Underflow

Underflow into the model area is listed on Table 2 and the general locations of the underflow are depicted on Figure 8. Most of the values are consistent with the pre-development estimates for the model area (Corkhill and others, 1993). The notable changes are:

1) As a result of the water logged area near Buckeye, an additional 1,000 AF/Yr over the predevelopment value of 2,000 AF/Yr is leaving the model area along the Gila River near Arlington.

2) Where the Santa Cruz River enters the model boundary the groundwater flow direction has reversed. During pre-development time, 13,000 AF/Yr entered the model, at that location in 1988 an estimated 24,000 AF/Yr left the model as a result of groundwater pumping in Pinal County (Corkhill and others, 1993).

3) Underflow into the model area from the Gila River near Florence has risen from less than 1,000 AF/Yr during pre-development time to an estimated 3,000 AF/Yr in 1988.

4) The pre-development underflow and infiltration from the Agua Fria River (9,000 AF/Yr) was not simulated in the model projections, reflecting the influence of Waldell Dam on the Agua Fria River.

Ephemeral Streams

The inflow of water into the model area from ephemeral streams was divided into two categories; 1) underflow and infiltration, 2) underflow. The ephemeral streams in the model area that contribute to the category of underflow and infiltration are; Cave Creek, Skunk Creek, New River, and Queen Creek (Figure 7). The total annual recharge and underflow from these ephemeral streams was estimated at 10,500 AF/Year (Corkhill and others, 1993) (Table 2).

The areas of groundwater underflow into the model area include the Gila River at Granite Knob and at Florence, North Hassayampa, and South Hassayampa (see Table 2 and Figure 7). These values were assumed to be representative of the underflow into the model and were held constant for the 1995 to 2025 projections.

Recharge

Recharge represents the major inflow to the groundwater system. The sources of recharge identified and simulated in the model include incidental recharge from agricultural and urban irrigation, seepage from canals and artificial lakes, treated effluent discharged into river channels, artificial recharge from underground storage and recovery projects, and naturally occurring recharge from flood flows along the major drainages and mountain fronts within the SRV model area. Inflow values for rivers and ephemeral streams, mountain front recharge, groundwater underflow, effluent, golf course recharge, urban lake recharge, and seepage from canals were derived from work discussed in Correl and Corkhill, 1994 (Table 2 and Table 3).

Recharge values for agriculture irrigation, underground storage and recovery projects were estimated in 5 year periods, starting in 1995. Recharge estimates that were held constant either at 1991 levels or at some other representative level include urban irrigation, effluent, seepage from canals and artificial lakes, treated effluent in stream channels and recharge from major drainages, and mountain front recharge (Table 3).

Overall, the recharge values in Table 1 decrease from 1995 to 2025, reflecting a decline in agricultural recharge due to the reduction in agricultural production. The decrease in agricultural recharge is not fully reflected in the recharge numbers until after 2010, due to the lag time required for the agricultural recharge to reach the water table. The increase in river recharge from 1991 to 2025 is the result of using historical recharge for the Salt River for the period 1964 to 1991. River recharge for this period was much higher then the calculated recharge for 1991 alone due to an unusual number of flood events. River recharge for this period is also much higher than the recharge calculated for the entire period of record that is available (early 1900's-1995).

A brief description of the methodology used to estimate recharge from each category is provided below. Refer to Corkhill and others (1993) for a more detailed description.

Table 1

Conceptual Groundwater Budget
For The SRV Model Area

(Values Rounded to Nearest 1,000 Acre-Feet)

Inflow to Groundwater System	**1991**	**1995**	**2010**	**2025**
Underflow In[1]	32,000	32,000	32,000	32,000
Recharge[2]	979,000	1,035,000	992,000	871,000
TOTAL INFLOW	**1,011,000**	**1,067,000**	**1,024,000**	**903,000.00**
Outflow from Groundwater System				
Underflow Out	27;000	27,000	27,000	27,000
Pumpage	953,000	902,000	1,090,000	1,378,000
Evapotranspiration	48,000	48,000	48,000	48,000
TOTAL OUTFLOW	**1,028,000**	**977,000**	**1,165,000**	**1,453,000**
∆ STORAGE	-17,000	90,000	-141,000	-550,000

[1] This category is broken down in more detail in Table 2.
[2] This category is broken down in more detail in Table 3.

Table 2

Estimated Groundwater Underflow and
Stream Channel Infiltration
SRV Study area (1983-1988)

(Figures Rounded to Nearest 500 Acre-Feet)

Groundwater Underflow Location	Acre-Feet/Year
INFLOW	
Underflow	
Gila River near Sacaton	7,000
Gila River near Florence	3,000
Hassayampa River near Morristown	3,000
Hassayampa River near Buckeye/Arlington	8,000
Total	**21,000**
Infiltration and Underflow	
New River	3,000
Skunk Creek	2,000
Cave Creek (north Phoenix)	2,000
Cave Creek (Paradise Valley)	1,500
Queen Creek	2,000
Total	**10,500**
TOTAL	**31,500**
OUTFLOW	
Santa Cruz River near Maricopa	24,000
Gila River near Arlington	3,000
TOTAL	**27,000**

Table 3

Estimated Recharge Values within the Salt River Valley Study Area

(Figures rounded to the nearest 500 Acre-Feet)

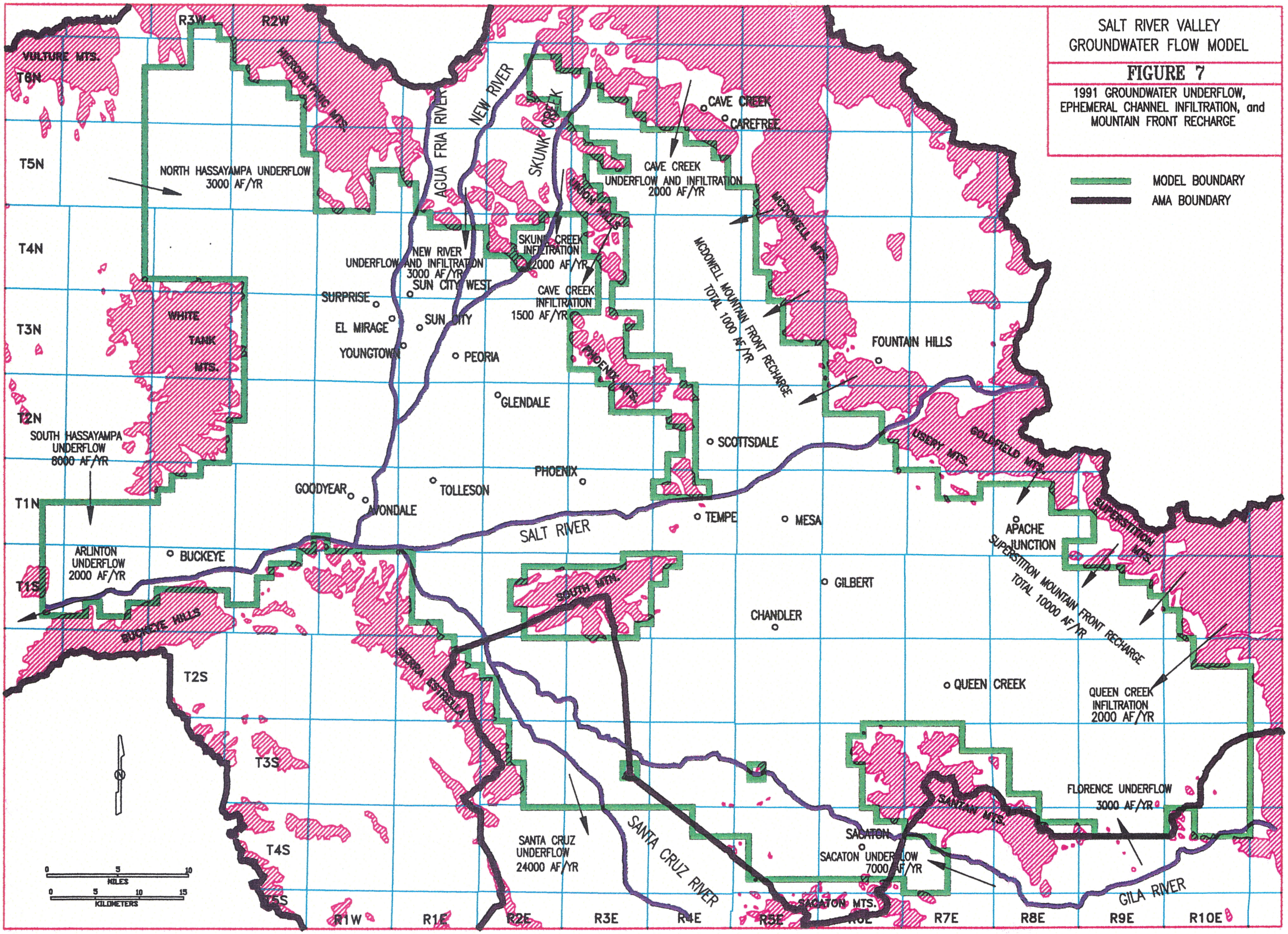
Recharge Categories		1991	1995	2010	2025
Agricultural		674,000	600,000	499,000	373,500
Urban (yards and parks)		33,000	33,000	33,000	33,000
Golf courses[1]		20,000	20,000	20,000	20,000
Canals		85,000	85,000	85,000	85,000
San Carlos Irrigation Project (1988)		41,500	41,500	41,500	41,500
Urban Lakes		13,000	13,000	13,000	13,000
Rivers[2]	Salt River	21,000	97,000	97,000	97,000
	Gila River	29,500	30,500	30,500	30,500
Effluent	91st Avenue	9,000	9,000	9,000	9,000
	23rd Avenue	37,000	37,000	37,000	37,000
Mountain Front		11,000	11,000	11,000	11,000
Recharge Projects		5,500	58,000	115,500	120,500
TOTAL		**979,500**	**1,035,000**	**991,500**	**871,000**

[1] Even though the demand for golf courses was increased over time the amount of recharge was not.

[2] Projected values, 1995 to 2025, are the average values from the period of 1964 to 1991.

Agricultural Irrigation

Agricultural recharge is one of the two variables calculated for each 5 year period from 1995 to 2025. The recharge was calculated using a two stages process. The first stage was estimating the agricultural recharge for 1991. The second stage was to estimate future recharge at 5-year intervals for the period 1995 through 2025 (e.g., 1995, 2000, etc.).



SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE 7
1991 GROUNDWATER UNDERFLOW, EPHEMERAL CHANNEL INFILTRATION, and MOUNTAIN FRONT RECHARGE
MODEL BOUNDARY
AMA BOUNDARY
VULTURE MTS.
HIEROGLYPHIC MTS.
NORTH HASSAYAMPA UNDERFLOW 3000 AF/YR
WHITE TANK MTS.
SOUTH HASSAYAMPA UNDERFLOW 6000 AF/YR
ARLINTON UNDERFLOW 2000 AF/YR
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
NEW RIVER UNDERFLOW AND INFILTRATION 3000 AF/YR
SKUNK CREEK INFILTRATION 2000 AF/YR
CAVE CREEK INFILTRATION 1500 AF/YR
CAVE CREEK UNDERFLOW AND INFILTRATION 2000 AF/YR
MCDOWELL MTS.
MCDOWELL MOUNTAIN FRONT RECHARGE TOTAL 1000 AF/YR
PHOENIX MTS.
CAVE CREEK
CAREFREE
FOUNTAIN HILLS
SURPRISE
SUN CITY WEST
EL MIRAGE
SUN CITY
YOUNGTOWN
PEORIA
GLENDALE
SCOTTSDALE
PHOENIX
GOODYEAR
AVONDALE
TOLLESON
TEMPE
MESA
BUCKEYE
SALT RIVER
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
APACHE JUNCTION
SUPERSTITION MOUNTAIN FRONT RECHARGE TOTAL 10000 AF/YR
SOUTH MTN.
GILBERT
CHANDLER
BUCKEYE HILLS
SIERRA ESTRELLA
QUEEN CREEK
QUEEN CREEK INFILTRATION 2000 AF/YR
SANTAN MTS.
FLORENCE UNDERFLOW 3000 AF/YR
SACATON
SACATON UNDERFLOW 7000 AF/YR
SACATON MTS.
GILA RIVER
SANTA CRUZ RIVER
SANTA CRUZ UNDERFLOW 24000 AF/YR
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S
T4S
T5S
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R7E
R8E
R9E
R10E
MILES
KILOMETERS

Agricultural recharge is one of the two variables calculated for each 5 year period from 1995 to 2025. The recharge was calculated using a two stages process. The first stage was estimating the agricultural recharge for 1991. The second stage was to estimate future recharge at 5-year intervals for the period 1995 through 2025 (e.g., 1995, 2000, etc.).

For 1991, the amount of water used and the location of the irrigated land was obtained by accessing ADWR's Registry of Grandfathered Rights database to obtain active Irrigation Grandfathered Rights (IGFR) and the reported water use per IGFR. Each IGFR has is allowed to irrigate a maximum number of acres using a maximum amount of water determined by 1975 to 1979 crop histories. ADWR receives annual reports of water delivered to each IGFR, but does not know the actual number of acres irrigated. Recharge estimates were made using the actual amount of water delivered to each IGFR, the average proportion of the maximum possible irrigation acreage that was actually irrigated, and the average efficiency for the Areas of Similar Farming Conditions (ASFC). The ASFCs are irrigation districts or group of districts with assumed similarities in farming practices. Using a Geographical Information System (GIS) the IGFR's and ASFC's were used to calculate the amount of water recharged and to determine where to locate the recharge spatially within the model.

Estimated future agricultural recharge assumed that the amount of water applied, farming efficiency, and the location of each active IGFR in 1991 would remain constant in the future, unless urbanization of the land occurred. For modeling purposes the amount of land irrigated within a modeling cell (i.e. the amount of farming) is assumed to remain constant. Realistically individual tracts of land may go in and out of production through the years but the projections assume the amount of land irrigated during any one year does not change. The 1991 irrigated land information was related to population projections from Maricopa Association of Governments (MAG) to determine when cultivated lands would be taken out of production due to urbanization. For the Current Trends Alternative scenario a density of one house per acre or 640 houses per square mile was considered as urbanized land. This method predicted slower rates of urbanization than expected, particularly in the SRP service area.

Recharge from agricultural irrigation was calculated using reported pumping data for the period 1989 to 1991 for each ASFC. For each ASFC the recharge was estimated utilizing data reported for each IGFR in the Phoenix AMA including historic water applied, crop mixture reported between 1980 and 1985, crop consumptive use based upon the historic crop mixture, estimated farm efficiency, and the historic reported percentage of actual farmed acres per IGFR. The GIS system was instrumental in being able to relate the IGFR data to the ASFC areas and ultimately to the SRV model grid. The information used to calculated the agricultural recharge was compiled by the Phoenix AMA.

Recharge for each ASFC was calculated based upon only those IGFRs that actually reported receiving water in 1991. The methodology to calculate recharge for each IGFR required numerous steps. The equations used to calculate the recharge for each ASFC are outlined below:

Step No. 1:

$$\text{Est. Actual Farmed Acres per IGFR} = \frac{\text{1991 water applied per IGFR} * \text{maximum historic irrigable acres per IGFR}}{\text{Second Management Plan Allotment}}$$

Step No. 2A:

$$\text{Est. Weighted Average Efficiency per IGFR} = \frac{\text{1991 water applied per IGFR} * \text{historic reported efficiency per IGFR}}{\text{total water applied to all IGFRs within the ASFC}}$$

Step No. 2B:

Cumulative Est. Average Efficiency per ASFC = the sum of the Est. Average Efficiency per IGFR

Step No. 3:

$$\text{Est. Average Consumptive Use per ASFC} = \frac{\text{1991 water applied to IGFRs within a ASFC} * \text{cum. est. avg. efficiency per ASFC}}{\text{total farmed acres within the ASFC}}$$

Step No. 4:

$$\text{Est. Recharge Rate per ASFC} = \frac{\text{total 1991 water applied to IGFRs within a ASFC}}{\text{total farmed acres for all IGFRs within a ASFC}} - \text{Consumptive Use per ASFC}$$

Step No. 5:

Est. Recharge per ASFC = est. actual farmed acres per IGFR * Recharge Rate per ASFC

A recharge lag time was introduced to take into account the transit time in the vadose zone as water travels from land surface downward to the water table. A downward velocity of 10 vertical feet per year was estimated based upon the characteristics of vadose zone flow. Therefore, the length of time it takes for water to reach the groundwater system varies through out the Salt River Valley with the depth to water in each area. Lag times were varied depending upon the regional depth to water based upon 1991 water levels. For example agricultural recharge from irrigation applied in 1991 in an area where the depth to water is 200 feet below land surface would reach the water table in 20 years or the year 2011. This is important considering the average cropped acreage in the model area was rather constant for the period 1968 through 1981 at 382,000 acres (Corell and Corkhill, 1994). Using crop-specific consumptive use values and estimated average irrigation efficiency of 62 percent the estimated agricultural recharge for this period was 825,000 AF/Yr. It is these higher rates of agricultural recharge that are currently reaching the water table. By comparison an estimated 347,000 AF/Yr entered the top of the vadose zone in 1991. Refer to Corell and Corkhill (1994) for a more detailed discussion on the concept of lag time.

Table 4 presents a summary of projected agricultural practices by Water Planning Areas (WPA) within the model domain for 1995. WPA's are areas of similar water demand and supplies as determined by the Phoenix AMA (Figure 8). The Phoenix AMA consulted with various municipalities and water providers to account for their projected growth in the future. The columns Farmed Land and Water Use are the calculated amounts of land irrigated and the amount of water used for irrigation. Possible Irrigated Land, in Table 4, is the total amount of land available for irrigation within the WPA, and Water Allotment is the amount of water available for irrigation within the WPA. The projected 1995 values presented in Table 4 were calculated from 1991 data. The only difference between the 1991 values and the projections for 1995 to 2025 is the reductions due to urbanization. The agricultural recharge used in the model was then determined by calculating the amount of lag time required for the water to reach the water table.

Projected recharge from agricultural irrigation was estimated into the future for each 5-year interval between 1995 and 2025. The method used to calculate recharge was identical to the steps above with the addition of three critical components. First, pumpage for an IGFR was removed from future simulation when the IGFR was determined to become urbanized based on population projections. The agricultural recharge for that area was continued into the future based on the lag time concept.

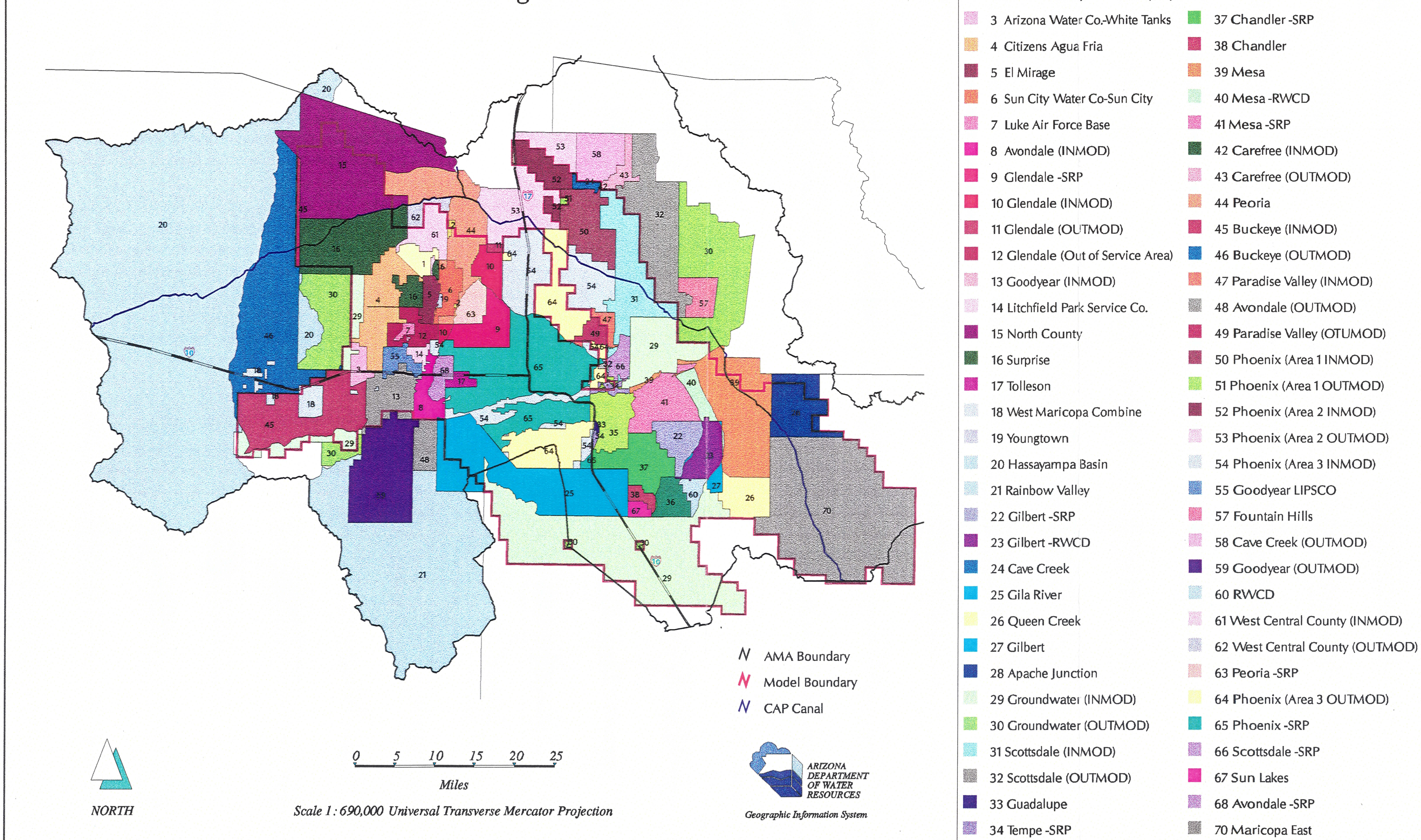


Figure 2
Water Planning Areas

Table 4a

Projected Agricultural Practices for the Salt River Valley Study Area for the year 1995

OUTSIDE SRP BOUNDARIES

WPA	WPA #	Farmed Land (Acres)	Water Use (AF/YR)	Possible Irr. Land (Acres)	Water Allotment (AF/YR)
Sun City West	1	0	0	0	0
Other Sun City Water Co.	2	0	0	0	0
Sun City	6	112	514	114	541
AZ Water Co. White Tanks	3	122	584	387	2,044
Citizens Agua Fria	4	6,294	32,156	10,999	57,382
El Mirage	5	596	2,530	1,103	4,626
Luke Air Force Base	7	5	28	7	39
Avondale	8,48	3,086	19,413	4,197	27,030
Glendale	10,11	836	5,146	1,276	7,905
Glendale-outs. service area	12	2,293	12,414	4,349	23,483
Goodyear	13,59	7,497	43,992	10,653	63,619
Goodyear-LPSCO	55	480	2,618	963	5,249
LPSCO	14	137	749	274	1,495
North County	15	1	3	23	109
West Central County	61	573	3,118	619	3,374
West Central County	62	0	0	0	0
Suprise	16	3,534	19,093	5,482	29,133
Tolleson	17	890	5,728	1,002	6,547
West Maricopa Combine	18	3,829	21,799	6,102	35,051
Youngtown	19	0	0	0	0
Hassayampa Basin	20	0	0	0	0
Rainbow Valley	21	0	0	0	0
Gilbert	23,27	10,281	45,269	13,115	58,071
Cave Creek	24	0	0	0	0

(Table 4a continued)

WPA	WPA #	Farmed Land (Acres)	Water Use (AF/YR)	Possible Irr. Land (Acres)	Water Allotment (AF/YR)
Gila River	25	9	55	12	72
Queen Creek	26	3,975	19,525	8,557	42,280
Apache Junction	28	0	0	0	0
Ground Water pumping	29	3,025	17,077	4,040	22,923
Ground Water pumping	30	0	0	0	0
Scottsdale	31,32	9	51	37	194
Guadalupe	33	-	-	-	-
Tempe	35	245	1,198	399	1,965
Chandler	36,38	5,609	32,438	8,006	47,540
Mesa	39,40	2,519	13,175	4,657	24,170
Carefree	42	0	0	0	0
Carefree	43	0	0	0	0
Peoria	44	328	1,715	645	3,662
Buckeye	45	22,379	132,388	31,048	187,037
Buckeye	46	0	0	0	0
Paradise Valley	47,49	6	35	23	119
Phoenix Area I	50,51	15	108	41	292
Phoenix Area II	52,53	1	3	10	33
Phoenix Area III	54,64	2,340	13,839	3,097	18,774
Fountain Hills	57	0	0	0	0
RWCD	60	2,655	13,722	3,702	19,248
Sun Lakes	67	797	4,723	986	5,843
Maricopa East	70	9,960	45,823	20,397	95,998

Table 4b
Projected Agricultural Practices
for the Salt River Valley Study Area
for the year 1995

INSIDE SRP BOUNDARIES

WPA	WPA #	Farmed Land (Acres)	Water Use (AF/YR)	Possible Irr. Land (Acres)	Water Allotment (AF/YR)
SRP					
Phoenix	65	17,236	94,434	21,671	127,052
Peoria	63	1,280	6,611	1,577	8,232
Mesa	41	626	2,961	1,053	5,104
Avondale	68	4,039	23,062	4,912	28,319
Glendale	9	3,045	17,044	3,534	20,108
Gilbert	22	3,436	18,175	4,362	23,475
Tolleson	17	890	5,728	1,002	6,547
Scottsdale	66	0	0	0	0
Tempe	34	0	0	0	0
Chandler	37	4,609	26,907	6,257	37,511
SRP TOTALS		**35,161**	**194,922**	**58,568**	**256,348**
TOTAL for all WPA's		**129,599**	**705,951**	**204,890**	**1,052,196**

The next component in determining agricultural recharge was the assumption that the crop type mixture and water usage for each IGFR remained constant at 1991 levels. The assumption that the agricultural practices of 1991 are representative of future conditions was developed out of meetings with various water providers and irrigation districts within the study area.

The third component was the assumption that farm efficiencies would not increase with time as mandated by ADWR's Second Management Plan. This was assumed since most irrigation districts have extensive amounts of flex-credits and would not necessarily need to change irrigation practices to comply with the more stringent efficiency requirements. Flex credits are the amount of water not used from Irrigation Grandfathered Rights (IGFR's) water allotment in any one year. Flex credits are cumulative with no upper limit on the amount of credits that can be obtained, and can be used at any time to supply more water to a crop than allotted to the IGFR. As of 1995 the total accumulated flex credits in the Phoenix AMA were approximately 5.5 MAF.

Urban Irrigation

Recharge from urban irrigation was broken down into facilities that have either turfed areas less than 10 acres (generally parks and schools) or greater than 10 acres (generally golf courses). The maximum potential recharge for each facility was calculated by subtracting the total consumptive requirement for each turfed area from the total reported water applied for each facility, assuming the turf was 100% bermuda grass (Corkhill and others, 1993). Recharge in 1988 for turf areas greater than 10 acres (golf courses) was estimated at 20,000 AF/Year, while recharge for areas less than 10 acres (urban recharge) was 33,000 AF/Year (Table 3). The values for urban and recharge from golf course irrigation were assumed representative for 1991 and held constant through out the Current Trends Alternative simulation.

Canals

Recharge from canal seepage was estimated for each of the major irrigation districts within the SRV. In general, seepage was calculated by multiplying a representative infiltration rate by the wetted area for each canal dependant upon whether the canal was lined or unlined (Corkhill and others, 1993). The total estimated recharge from all canals for 1988 was 85,000 AF/Year (Table 3). This value was assumed representative of 1991 and was held constant through out the Current Trends Alternative simulation.

The recharge from the San Carlos Irrigation Project (SCIP) was calculated separately based upon water delivery data supplied from SCIP annual reports (SCIP, 1978-1988). The maximum potential recharge from SCIP canal seepage in the SRV study area was apportioned to each canal base upon the average wetted perimeter, and total canal length. Recharge was aerially distributed along each canal in proportion to the length of canal per section (Corkhill and others, 1993). The recharge for 1991 was estimated to be 41,500 AF/Year, this values was held constant in this scenario to 2025.

Urban Lakes

Seepage from artificial lakes greater than 10 acres in size were considered potential sources of localized recharge. The annual estimated recharge volume from artificial lakes for 1991 was estimated by multiplying the total lake acres by an infiltration rate dependant upon whether the lake was lined or unlined (Corkhill and others, 1993). The total annual recharge estimates for 1991 was 13,000 AF/Year and held constant through the scenario.

Rivers

Recharge from the major rivers in the model area, the Salt River and the Gila River, was calculated separately from the underflow associated with the rivers. The recharge calculations utilized streamflow data obtained from the stream gages operated by the USGS. Recharge along the Salt River was calculated for 1991 at 21,000 AF/Yr based on actual flows. For the projections of future conditions the average streamflow between 1964 and 1991 was used to calculate a recharge value of 97,000 AF/Yr for the Salt River in the model area (Correl and Corkhill, 1994). The recharge calculated for the Gila River during 1991 was 29,500 AF/Yr based on actual stream flows. Utilizing the average streamflow on the Gila River between 1964 to 1991, a value of 30,500 AF/Yr was used for the projected recharge from 1995 to 2025. No underflow and infiltration from the Agua Fria River were simulated in the model projections, reflecting the influence of Waldell Dam on the Agua Fria River. This recharge estimate is substantially higher than the estimate that would be derived in the long term streamflows of the Salt and Gila Rivers were used. The period 1964-1991 contained a higher than normal number of flood events that caused higher than normal river recharge to occur.

Effluent

Recharge from treated effluent discharged into stream channels was estimated for the City of Phoenix's 23rd Avenue and 91st Avenue waste water treatment plants (WWTP), Avondale WWTP, Goodyear WWTP, and Luke AFB WWTP. However, the two City of Phoenix WWTPs are the only treatment plants that discharge regionally significant volumes of effluent that might contribute to groundwater recharge (Corkhill and others, 1993). Estimates for the 23rd Avenue WWTP assumed 100% of the effluent discharged into the Salt River was recharged into the groundwater system. Approximately 37,000 AF/Yr was discharged from the plant between 1983 and 1988 (Corkhill and others, 1993). This average annual discharge was assumed representative of 1991 and held constant throughout the Current Trends Alternative simulation (Table 3).

Recharge from the 91st Avenue WWTP was estimated to be substantially less than the 23rd Avenue WWTP due to the very shallow groundwater levels downstream of the plant. The shallow groundwater levels limit the space available in the aquifer for recharge. Only a small percentage of the total volume of effluent discharged into the Gila River was considered to recharge the groundwater system. Approximately, 9,000 AF/Year was estimated to recharge between the 91st Avenue WWTP and the Buckeye Heading downstream (Corkhill and others, 1993). This value was held constant throughout the CTA simulation (Table 3).

Mountain Front Recharge

Recharge from precipitation along mountain fronts was considered to be only a small portion of inflow into the modern groundwater system. Only the McDowell and Superstition Mountains are significantly large enough to have a noticeable recharge contribution to the groundwater system. The mountain front recharge connected with the McDowell Mountains was estimated at 1,000 AF/Yr, and the estimated recharge from the Superstition Mountains was 10,000 AF/Yr (Corkhill and others, 1993). These values were assumed constant through out the CTA simulation (Table 3).

Recharge Projects

Only currently permitted or nearly permitted recharge projects, as of the development of the model in 1993, were included in this scenario (Table 5). Recharge volumes used in the model are as described in the permit for the facility, with the exception of the Granite Reef Underground Storage Project (GRUSP). Even though all the recharge projects were not permitted out to 2025 it was assumed that the permits would be renewed. In lieu recharge facilities, primarily located within the East SRV, were not included in the CTA.

In the area around the GRUSP site, the model simulated water levels above land surface, even when optimistic aquifer parameters were assumed by ADWR. The hydrogeological parameters in the model were altered to the high range of possible limits, however, the water levels remained above land surface using the purposed 150,000 AF/Yr recharge rate. Eventually it was necessary to reduce recharge values at GRUSP from 2010 thru 2025 to half of the planned rate (150,000 AF/Yr to 75,000 AF/Yr) to keep groundwater levels below land surface. Further research is needed to determine if the model is accurately representing the area around GRUSP. Table 5 list the recharge amounts used in the model for the various recharge facilities.

Table 5

Withdrawal Schedules of Permitted Underground Storage & Recovery Projects Current Trends Alternative

Acre-Feet/Year

Projects	1989	1990	1991	1995[1]	2000[2]	2005[2]	2010[2]	2015[2]	2020[2]	2025[2]
Town of Gilbert[3] 739	1660	1667	1871	2500	3271	3314	3314	3314	3314	
Mesa NWWRP[4]	0	206	3749	3833	4000	4000	9000	9000	9000	9000
Mesa Spook Hill[5]	0	0	0	0	2000	2000	2000	2000	2000	2000
Mesa NEWRP	0	0	0	8333	20000	25000	12500	12500	12500	12500
Ocotillo[6]	0	0	0	908	0	0	0	0	0	0
Phoenix Injection[7]	0	296	25	0	0	0	0	0	0	0
Scottsdale Water Campus[8]	0	0	0	80	5000	5000	5000	5000	5000	5000
Del E. Webb[9]	0	0	0	1313	2875	3041	3041	3041	3041	3041
GRUSP[10]	0	0	0	50000	120000	150000	75000	75000	75000	75000
Avondale[11]	0	0	0	0	5000	10000	15000	20000	20000	20000
Chandler Intel[12]	0	0	0	0	3100	3100	3100	3100	3100	3100

NOTES:

1. 4 year annual average between 1992-1995
2. 5 year annual average between 1996-2000, 2001-2005, 2006-2010, 2011-2015, 2016-2020, 2021-2025
3. Permit expires in 2013, but assumed to continue at 2002 value from (7/93) Table, may increase to 10,000 AF/Yr within next 10 years due to Augmentation grant.
4. Permit expires in 2008, increased to 8 MGD (~9000 AF/Yr) in 2006
5. Permit expires in 2008, projected at 2000 AF/Yr using CAP water and assumed constant after 2008
6. Permit expires in 1994 (plan on renewing permit for up to 5000 AF/Yr by 1995)
7. Permit expires in 2009, NOT simulated after 1991
8. Permit expires in 1994, current permit for 1300 AF/Yr and maybe increase to 5000 AF/Yr in future
9. Permit expires in 2043
10. Permit expires in 2010, but assumed to continue at 2002 value from (7/93) Table. Reduced from 2006 to 2025 so water level does not go above land surface.
11. Permit expires in 1996, assumed to be expanded to full US&R project and incremented according to City of Avondale discussions. Assumed to increase 5,000 AF/Yr every 5 years.
12. Permit expires March 2, 2014, assumed to continue at same rate after permit expiration

Outflow

There are three components of outflow from the groundwater system: groundwater underflow out of the basin, pumpage, and evapotranspiration from riparian vegetation along the Salt and Gila Rivers (Corkhill and others, 1993).

Outflow estimates from groundwater and evapotranspiration underflow were held constant at 1991 levels throughout the Current Trends Alternative simulation. The reported pumping information was used for 1989 to 1991 in the model simulation. The projected pumpage from 1995 to 2025 was estimated for each 5-year interval. A brief description of the methodology used to estimate outflow from each category is provided below.

Underflow

Groundwater underflow out of the model was simulated in two locations, at the Gila River near Arlington, and near the Santa Cruz River near Maricopa-Stanfield (Corell and Corkhill, 1994). Groundwater underflow at the Gila River near Arlington was estimated for 1988 at 3,000 acre-feet. This value was assumed representative of future conditions and was held constant throughout the Current Trends Alternative simulation.

Underflow out of the model near Maricopa-Stanfield was estimated from the Pinal AMA groundwater flow model (Corkhill and Hill, 1990). This underflow was estimated for 1988 at approximately 24,000 acre-feet and was assumed representative of future conditions and held constant throughout the CTA simulation.

Pumpage

Pumpage represents the major outflow from the modern groundwater system and was obtained in two stages. First, pumpage was estimated for 1991 using ADWR's Registry of Grandfathered Rights (ROGR) database to obtain the total reported annual non-Indian pumpage for wells within the Phoenix AMA. The second part was to estimate future pumpage at 5-year intervals between 1995 and 2025 (e.g., 1995, 2000, etc.). The estimated pumpage for the future was spatially distributed based on current well locations and on the locations of future supply wells. If the location of future supply wells were not provided by the water providers the groundwater demand was spread evenly through out the WPA by simulating wells approximately every mile within the WPA. Total pumpage within the model domain was projected to increase approximately 32%, from 950,000 acre-feet in 1991 to 1,255,000 acre-feet by 2025.

The total annual pumpage for 1991 was estimated for both non-Indian uses (e.g., municipal, industrial and agricultural) and Indian uses (eg, agricultural). All non-Indian pumpage greater than 10 acre-feet per year is required to be reported to the ADWR within the Phoenix AMA. The total annual reported non-Indian pumpage for 1991 was approximately 835,000 acre-feet.

Indian pumpage for 1991 within the model domain had to be estimated since no data exist for either the Salt River-Pima Maricopa Indian Community (SRPMIC) or the Gila River Indian Community (GRIC) (Corkhill and others, 1993). A water budget approach was used to estimate the pumping for the period between 1989 and 1991. This approach essentially computed an annual water use requirement for each Indian community based on an assumed value of effective consumptive use (consumptive use divided by irrigation efficiency) and reported cropped acreage provided by the U.S. Bureau of Indian Affairs (BIA) crop reports.

Pumpage from SRPMIC was estimated at 24,000 acre-feet for 1991 using the water budget methodology and was assumed constant throughout the CTA simulation. Pumpage estimates for the GRIC were obtained from San Carlos Irrigation District (SCIP) annual reports for areas "on-project". For the areas "off-project" the same water budget methodology was used to estimate pumpage. Pumpage reported by the SCIP for 1991 was approximately 24,000 acre-feet. Pumpage for agricultural lands "off-project" was estimated at 68,000 acre-feet for 1991. The total pumpage for 1991 from the GRIC was estimated at 92,000 acre-feet and was assumed constant throughout the CTA simulation. Non agricultural pumping for the Indian communities was assumed to be minor and not estimated.

Future pumpage (after 1991) was estimated at 5-year intervals between 1995 and 2025. In general pumpage volumes and locations were assumed to remain constant at 1991 levels, except for the reduction in pumpage due to the urbanization of agricultural lands or the increase in pumpage based upon population projections and changes in how the municipalities or water providers would supply the water. Reduction of pumpage from 1991 levels due to the urbanization of agricultural lands was estimated by utilizing GIS capabilities to compare the spatial location of agricultural lands within the urbanization patterns predicted by MAG. If an IGFR was predicted to become urbanized then all agricultural wells within that IGFR boundary were removed from further simulations. The exception to the wells being turned of were the Salt River Project Irrigation District, Roosevelt Irrigation District, and Roosevelt Water Conservation District. In these districts alternative uses have been planned for their urbanized wells. For the CTA the criteria of one house per acre at the traffic analysis zone (TAZ) level was used to determine if an area urbanized or not. This permitted the simultaneous reduction in agricultural pumpage as agricultural lands converted to urban uses plus increasing urban demands. Two exceptions to this general practice were Roosevelt Irrigation District, which indicated that their water deliveries would shift to eligible but currently un-farmed IGFR lands as currently farmed lands urbanized, and Roosevelt Water Conservation District, which indicated that their IGFRs would convert to mini-farms with the same overall water demand.

New municipal supply wells were created and distributed for the simulation as discussed below. The municipal pumpage was increased above 1991 levels based upon population projections. Figure 8 illustrates zones called Water Planning Areas (WPA) that were selected by ADWR to delineate unique water supply sources and demand areas (eg., groundwater, surface water, Salt River Project, CAP). Pumpage was increased as housing units increased in those WPA's in which future municipal water demand is projected to be supplied by groundwater. The projected demand was estimated by multiplying the projected housing units by the calculated 1991 demand ratio (gallons per housing unit, GPHUD) for each provider. The total water demand was split by supply source according to how the municipalities and water providers indicated they would meet the demand (i.e. groundwater, surface water, or CAP). The projected municipal groundwater demand was distributed proportionally to the 1991 municipal pumping locations in an attempt to accurately model future pumping within a WPA. When the projected groundwater demand exceeded the municipal pumping for 1991 the remaining amount of pumping was either assigned to new well locations as indicated by city planners, or when that information was not available, the pumping was spread evenly throughout the WPA.

The water demand for future golf courses and other turf facilities was included in the projected municipal water demand. The ratio between golf courses and population varied by provider and historic water use, but as population increased the ratio was kept constant for each WPA unless the WPA was completely developed. The efficiency for the new golf courses was kept consistent with the 1991 values calculated for each WPA. The water use for the increase in golf courses was added to the municipal demand. Appendix AII contains additional details on the assumptions used to generate pumpage estimates for the WPAs.

Evapotranspiration

Evapotranspiration (ET) from riparian vegetation occurs along the Salt and Gila Rivers downstream of the City of Phoenix's 23rd Avenue Waste Water Treatment Plant. Phreatophyte growth is prolific in areas where the depth to water is less than 20 to 30 feet below land surface. Corkhill and others (1993) estimated the maximum ET for 1987 to be 83,000 acre-feet, based on plant areal distribution, type and density. ET from phreatophytes was calibrated within the SRV model at 48,000 AF/Yr. The estimate from the calibrated SRV model was assumed to be representative of future conditions and held constant throughout the CTA simulation.

THE SRV GROUNDWATER FLOW MODEL

General Approach

The regional numerical groundwater flow model for the Salt River Valley (SRV) developed by Corell and Corkhill (1994) is approximately 2,240 mi^2 in size and incorporates portions of both the East and West Salt River Valley sub-basins (Figure 1.). The model was calibrated for steady-state hydrologic conditions (ie, circa 1900) and transient conditions between 1983 and 1991. The model was used to simulate hydrologic conditions between 1989 and 2025 in 5-year increment starting with 1995 and ending with 2025. Projected water supply and demand for both municipal and industrial (M & I) and agricultural sectors were estimated for each 5-year increments.

General Features of the Model

The active model domain encompasses 2,240 mi^2 and contains most of the East and West SRV sub-basins of the Phoenix AMA, and the northern- most portion of Maricopa-Stanfield sub-basin of the Pinal AMA. The model is quasi-three-dimensional and contains three layers that correspond to the alluvial hydrogeologic units within the SRV. The uppermost layer, Layer 1, corresponds to the Upper Alluvial Unit (UAU) which is modeled as an unconfined aquifer. The middle layer, Layer 2, corresponds to the Middle Alluvial Unit (MAU) and is modeled as a confined/unconfined aquifer. This layer is modeled as confined when the overlying UAU is saturated and unconfined when the UAU is dewatered. The lowermost layer, Layer 3, corresponds to the Lower Alluvial Unit (LAU) and is also modeled as a confined/unconfined aquifer. The layer is modeled as confined where the overlying MAU is saturated and unconfined where the MAU is dewatered. The Red Unit which occurs in east Phoenix and Scottsdale is included in the LAU due to its similar hydrologic properties and limited areal extent. Near the basin margins, the bottom of Layer 3 corresponds to the geologic contact of the basin-fill and crystalline basement bedrock. Towards the basin centers where the basin-fill deposits are very thick, the bottom of Layer 3 parallels land surface elevations with a maximum depth of 3,000 feet below land surface. The maximum thickness of 3,000 feet for the lowermost layer was selected in part, because no pumping wells are deeper than 3000 feet in the model study area (Corkhill and others, 1993).

For a more detailed discussion regarding the modeling of the hydrogeologic units, refer to Appendix I and Corell and Corkhill (1994).

MODEL RESULTS

Model Projections of Future Conditions

Using the Salt River Valley Groundwater Flow Model, future groundwater conditions were projected using the previously mentioned water demand and supply assumptions. The simulated water budget values from the model are presented in Table 6. Graphically the results of the Current Trends Alternative projection are shown in Figures 9 thru 11. The water budget produced by MODFLOW code was altered to closer represent the categories used in the conceptual water budget for easier comparison. Most of the variation between the simulated values and the conceptual values is related to how the model handles the underflow from the Hassayampa River near the Buckeye/Arlington area. In 1991 15,000 AF/Yr of underflow was coming into the model from the Hassayampa sub-basin. As projected water levels rise in this area only 7,000 AF/Yr is simulated as underflow coming into the model area by the year 2025.

The model also provides values for recharge plus a value for the amount of water entering the groundwater flow system from the perennial portions of the Gila River. Even with these two values combined, the simulated recharge value is less than the conceptual recharge estimates for most of the simulation. The conceptual recharge values from 1991 to 2010 are approximately 30,000 to 40,000 AF/Yr higher than the simulated recharge values or 3% higher than the simulated recharge values. Two possible explanations for the slight variance in values can be attributed to agricultural recharge being applied to areas of the model that became dry (therefore the cells were turned off), and to the variability associated with the constant head cells in the model.

The simulated underflow out of the model system increases as the water levels increase in the Arlington area where the Gila River exits the model area. The difference in the conceptual pumping demand versus the simulated pumping demand occurs for a similar reason as the recharge difference. If the model cell becomes dry the pumping demand is not subtracted from the groundwater flow system. For this scenario when a layer became dry, the well was deepened to the next layer if possible. When there was not a deeper aquifer then it was assumed the water demand was meet by some other source besides groundwater. The decrease in the simulated evapotranspiration is a result of the groundwater being drawn below the cutoff level for phreatophyte use especially along the Salt River in the West Salt River Valley (WSRV) (Figure 11).

Table 6

Water Budget - Transient-State (1989-2025)
SRV Groundwater Flow Model
(Values Rounded to Nearest 1000 Acre-Feet)

Inflow to Groundwater System	**1991**	**1995**	**2010**	**2025**
Underflow In[1]	38,000	36,000	30,000	29,000
Recharge[2]	950,000	1,003,000	951,000	874,000
TOTAL INFLOW	**988,000**	**1,039,000**	**981,000**	**903,000**
Outflow from Groundwater System				
Underflow out[3]	28,000	32,000	43,000	44,000
Pumpage[4]	936,000	872,000	1,022,000	1,255,000
Evapotranspiration	42,000	44,000	41,000	36,000
TOTAL OUTFLOW	**1,006,000**	**948,000**	**1,106,000**	**1,335,000**
Δ STORAGE	-18,000	91,000	-125,000	-432,000

[1] Constant head underflow plus ephemeral stream underflow and infiltration minus 11,000 AF/Yr mountain front recharge (modeled as injection wells).

[2] Includes: agricultural, urban, golf courses, canals, rivers, effluent, and recharge projects. Plus 11,000 AF/Yr Mountain Front recharge modeled as underflow (i.e. injection wells). Plus the amount of surface water along the perennial portion of the Gila River, calculated by the model, that goes into the groundwater flow system.

[3] Constant Head from the model budget plus 24,000 AF/Yr underflow modeled as pumping. Plus the amount of groundwater calculated by the model that goes into the perennial portion of the Gila River.

[4] The amounts of pumping are less than originally were simulated in the model because of cells becoming dewatered in all three layers.

Over all, the 1991 simulated inflows and outflows were within a maximum of 4 percent of the 1991 conceptual estimates, however, by the year 2025 the maximum difference was 12 percent between the conceptual and the simulated water budgets. The higher percent difference for the 2025 data is largely a result of a model cell being "turned off" when it is dewatered and the demand or recharge not being transferred to a different location.

The Change of Storage (Δ Storage) listed at the bottom of Table 6 is a rough indicator, on a model wide basis, whether water levels went down or up. Positive numbers indicate an overall groundwater level rise and negative represents an overall groundwater level decline. The positive change in storage for 1995 indicates a groundwater rise in the model area reflecting the recharge amounts surpassing the demands on the groundwater system. The groundwater declines projected over most of the model area in later years are reflected in the increasingly negative changes in storage for 2010 and 2025.

For simplicity only the Middle Alluvial Unit (MAU) is represented within the body of this report. The MAU is commonly used by municipalities and agricultural wells in the model area and best represents the average water level conditions. The maps for the Upper Alluvial and Lower Alluvial units are presented in Appendix III. The Middle Alluvial Unit is representative of the overall changes predicted in the groundwater system, however, there are slight variations in the Upper and Lower Alluvial Units. Figure 9 shows the projected water levels in the year 2025. The notable changes are categorized by subbasin. Compared with 1991 conditions (Figure 6), the evident changes in the WSRV are:

Changes in the West Salt River Valley (WSRV) Please refer to Figures 9,10, and 11 for this discussion.

- In the WSRV groundwater will flow even more strongly to the cone of depression in the Luke Sink, but the deepest point in the Luke Sink will move to the northeast under the Sun City/Peoria area. This reflects the following assumptions: urbanization of farmland, the dependance primarily on groundwater to meet the demands of the water users, and the increasing role that municipal and turf use will play in the groundwater demand picture.

- Groundwater levels in the MAU are projected to drop approximately 300 feet in the Sun City and Peoria areas by the year 2025 and a lesser amount in other parts of the WSRV (Figure 7). Dewatering of the Middle Alluvial Unit (MAU) aquifer is projected to occur north of this area were the alluvial deposits thin towards the mountains.

- The Upper Alluvial Unit (UAU) is predicted to have drawdown of up to 175 feet from 1989 to 2025. Parts of the UAU aquifer are dewatered by the year 2025. One area that was dewatered at the start of the simulation (1989) between the Phoenix Mountains and South Mountain expanded further to the west into the WSRV sub-basin by the year 2025. A smaller area of the UAU aquifer, south of Youngtown, is also projected to be dewatered by the year 2025.

- The Lower Alluvial Unit (LAU) is estimated to have a maximum drawdown of 250 feet from 1989 to 2025, basically reflecting the general drawdown pattern depicted in the MAU. Unlike the UAU and MAU aquifers the LAU was not projected to have any areas that were to dewater in the WSRV.

- Projected depths to water in the year 2025 are predicted to exceed 700 feet in parts of the WSRV (Figure 11). The negative implications of this further drop in water levels are increased land subsidence, increased pumping costs and possible water quality problems. Along with the physical implications, the Assured Water Supply program allows a maximum depth of 1,000 feet over the next 100 years. If the projected water level declines at 2025 are continued another 75 years, water levels will approach this 1,000 ft. depth limit well before the 100 year period is up in some areas, such as the Sun City and Peoria.

- Continued drops in the water table in the WSRV will create further problems concerning subsidence in an area where a problem has already been documented and new problem areas are developing.

- To the south, along the Gila River, much of the groundwater that now flows parallel to the Gila River and eventually out of the AMA, will flow northward toward the Luke Sink instead.

- The water quality in the WSRV may degrade as the contaminants "floating" on the uppermost water in the aquifer at this time are drawn down into the lower part of the aquifer. In addition high nitrate and total dissolved solids (TDS) water along the river may be drawn laterally into adjacent portion of the aquifer due to the expanding Luke cone of depression. Indications from other work done by the Department are that vertical movement of several hundred feet would occur in the next 30 years in some areas, and that lateral movement of up to one mile would occur.

Changes within the East Salt River Valley (ESRV) Please refer to Figures 9,10, and 11 for this discussion.

- The changes in the ESRV are a result of increased municipal demand combined with the effects from artificial recharge sites, specifically GRUSP, supplying water to the central portion of the ESRV. Groundwater use is proportionately less of the supply than in the WSRV, therefore, the projection shows less of a change in the groundwater table. In the central portion of the ESRV the flow is projected to alter from flowing into smaller sinks along the edge of the model to a single cone of depression east of Chandler. Groundwater flow in the northern part of the ESRV is projected to alter from flowing southward in to the Paradise Valley sink to flowing north into a cone of depression in north Scottsdale.

- The UAU in the ESRV shows the impact from the GRUSP recharge project. The projected water levels in that area depicts a rise of 75 feet between the years 1983 and 2025. The maximum drawdown in the UAU was over 100 feet east of Gilbert. In the MAU, the GRUSP recharge project had a bigger impact raising the water levels in that area over 250 feet between 1983 and 2025.

- In lieu recharge projects were not included in the CTA simulation. These projects substitute use of CAP water for groundwater, thus reducing pumping in the area and allowing groundwater levels to remain at higher levels. Most in lieu projects are in the East SRV. If in lieu use of CAP water were simulated, the effect would be to show higher groundwater levels in the areas of substitution.

- Groundwater levels in the MAU are projected to drop approximately 300 feet in the north Scottsdale areas by the year 2025, dewatering portions of the MAU and LAU (Figure 11). The other major drawdowns in the ESRV in by the year 2025 include an area southeast of Chandler and Gilbert with over 100 feet of projected drawdown. Dewatering of the MAU also is projected to occur east of the Phoenix Mountains, west of Apache Junction, and southwest of Queen Creek.

- The drawdown in the LAU basically follows the same pattern as depicted in the MAU except for the north Scottsdale area where 650 feet of drawdown is predicted compared to 300 feet in the MAU. The drawdown is greater in the LAU reflecting a thicker aquifer than the MAU. In the area of 650 feet of drawdown in the LAU the MAU aquifer is completely dewatered.

- In the north Scottsdale area the projected depth to water exceeds 800 feet in 2025 (Figure 11). If the rate of decline suggested by the model is extended out 100 years this area would not meet the AWS supply rules. It should be noted that for the CTA all golf courses in north Scottsdale (WPAs 31 and 32) were assumed to remain on groundwater. Since the modeling work was completed for this report the planned sources of water for at least some of these golf courses has changed to CAP water. In the CTA model run the turf-industrial water demand was assumed to be 50 gphud, and all other demands totaled 591 gphud, thus the maximum over-simulation of groundwater use by turf facilities is about 8%. This may have caused a slight over-simulation of drawdowns in some areas of North Scottsdale.

- In numerous areas of the ESRV projected groundwater levels in the year 2025 are showing a rise due to a combination of factors including use of renewable source of water such as surface water and CAP water; recharge projects; less pumping for agricultural purposes; and recharge from agricultural irrigation in the 1970's reaching the water table during this projection period due to the lag time.

- The projected water demand of the Apache Junction WPA were based on the 1991 population. The population projections for this area were not available at that time. It is relatively safe to assume that population will grow in this area and hence the groundwater demand. The projected depth to water in the year 2025 (Figure 11) will probably be greater than depicted.

Cautions and Limitations

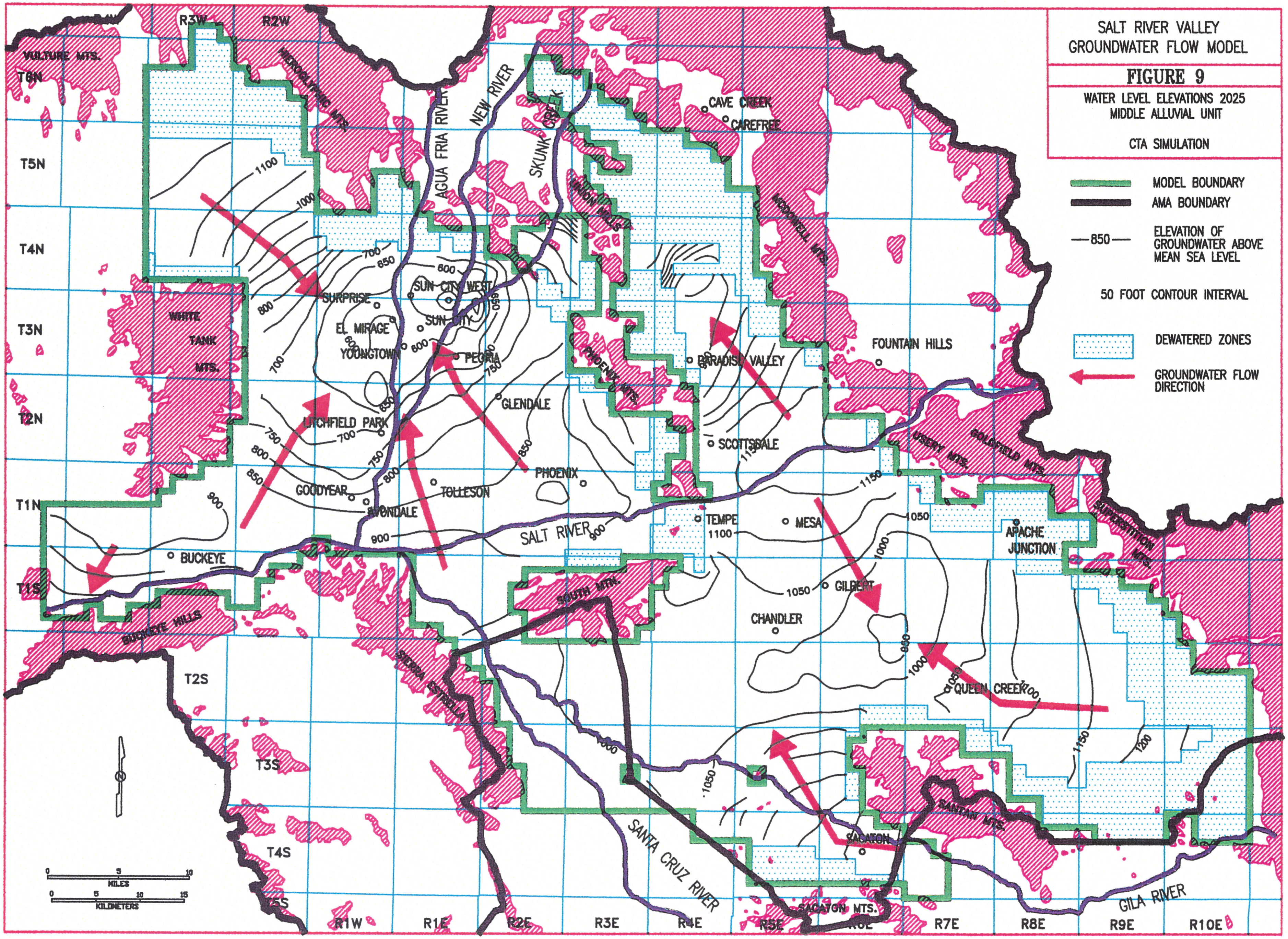
General Cautions

The model predictions should be viewed as an indication of future trends, but not as a precise measure of future groundwater conditions. Thus, while depths to groundwater in the Peoria area are predicted to be about 700 feet in 2025, one should interpret that to mean that this area will have the deepest depths to water in the WSRV and would approach the physical limit under the Assured Water Supply Rules sooner than other areas of the WSRV. One should not expect that depths to water in 2025 will be exactly 700 feet in that location.

The model is meant to be a regional planning tool. The model results are directly dependant on the assumptions made concerning water demands and water supply sources. In the CTA, most of the WSRV municipalities were assumed to depend mostly or entirely on groundwater. Assuming dependance on renewable supplies such as CAP water or effluent, or assuming the presence of a regionally significant groundwater recharge facility in the northern or central WSRV, would greatly modify future groundwater conditions as simulated by the model.

All of the model variables have been calculated to best represent the specific square mile cell of the model. The data with in the model is not intended to analyze area less than a square mile in size. The results of using the model as a predictive tool are very dependant on the assumption applied to the future. This is especially true with the assumptions used for the boundary conditions since they can be greatly affected by conditions outside the model area.

The amount of projected groundwater demand is under simulated in the model as a result of portions of the model area being dewatered. If one of the layers is dewatered or "dry", the model considers that area and layer (i.e. cell) as inactive or turned off. If the UAU or MAU was dewatered the associated pumping was moved to the next deeper layer, however, once the LAU was dewatered the pumping was not moved to a different cell. The under simulated groundwater demand is concentrated in areas along the edge of the model where the aquifers are thinner and in areas of projected large declines. This would explain the larger discrepancy between 2025 simulated and conceptual pumpage values verse the conceptual and simulated pumpage in 1991. With the larger demand in 2025, more model areas were dewatered resulting in more cells being "turned off".


SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE 9
WATER LEVEL ELEVATIONS 2025
MIDDLE ALLUVIAL UNIT
CTA SIMULATION
MODEL BOUNDARY
AMA BOUNDARY
850
ELEVATION OF GROUNDWATER ABOVE MEAN SEA LEVEL
50 FOOT CONTOUR INTERVAL
DEWATERED ZONES
GROUNDWATER FLOW DIRECTION
VULTURE MTS.
WHITE TANK MTS.
BUCKEYE HILLS
SIERRA ESTRELLA
SOUTH MTN.
PHOENIX MTS.
MCDOWELL MTS.
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
SANTAN MTS.
SACATON MTS.
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
SALT RIVER
SANTA CRUZ RIVER
GILA RIVER
CAVE CREEK
CAREFREE
SURPRISE
EL MIRAGE
YOUNGTOWN
SUN CITY WEST
SUN CITY
PEORIA
GLENDALE
LITCHFIELD PARK
GOODYEAR
AVONDALE
TOLLESON
PHOENIX
BUCKEYE
PARADISE VALLEY
SCOTTSDALE
FOUNTAIN HILLS
TEMPE
MESA
GILBERT
CHANDLER
APACHE JUNCTION
QUEEN CREEK
SACATON
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S
T4S
T5S
R3W
R2W
R1W
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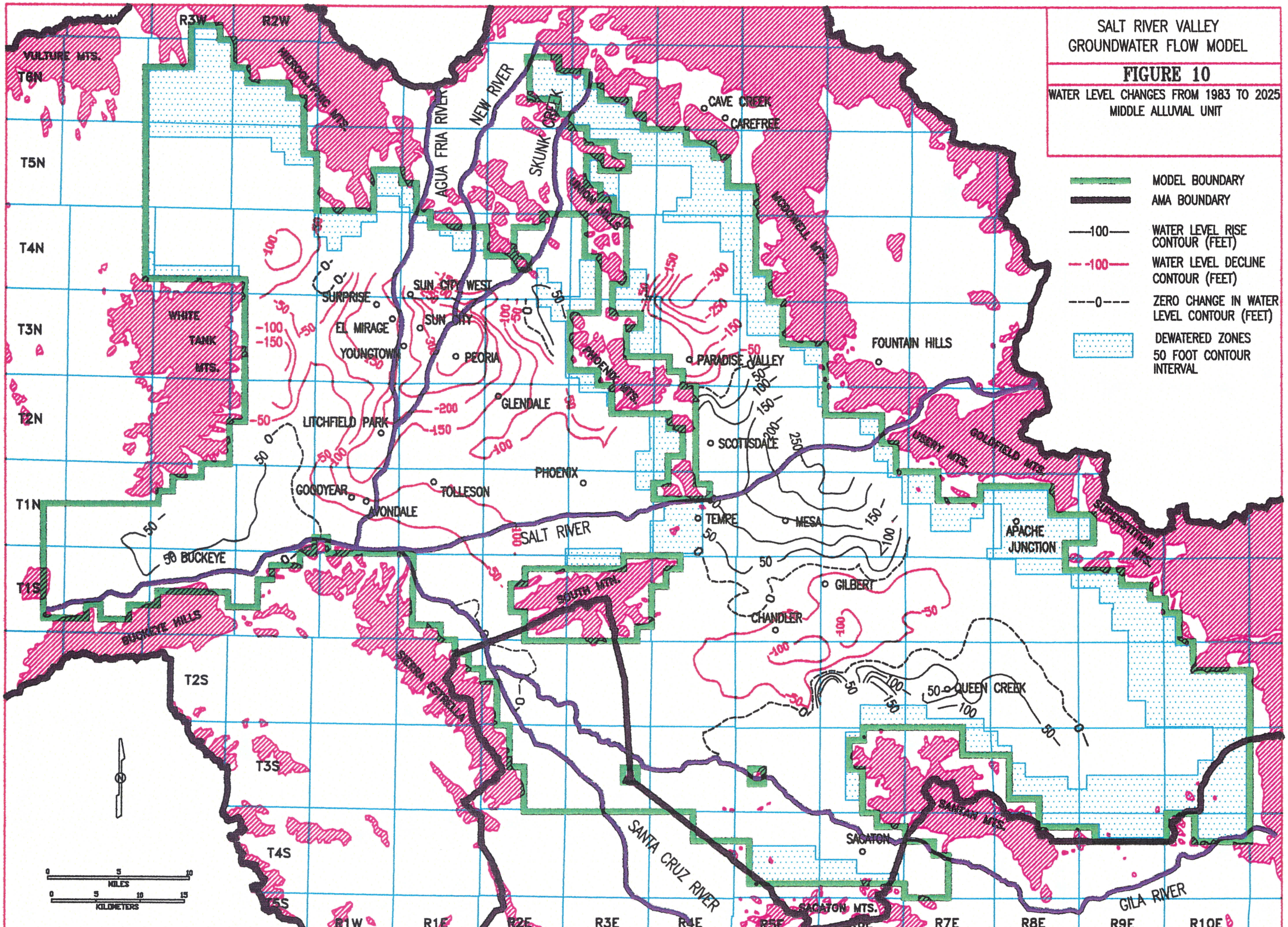

SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE 10
WATER LEVEL CHANGES FROM 1983 TO 2025
MIDDLE ALLUVIAL UNIT
MODEL BOUNDARY
AMA BOUNDARY
WATER LEVEL RISE CONTOUR (FEET)
WATER LEVEL DECLINE CONTOUR (FEET)
ZERO CHANGE IN WATER LEVEL CONTOUR (FEET)
DEWATERED ZONES
50 FOOT CONTOUR INTERVAL
VULTURE MTS.
WHITE TANK MTS.
BUCKEYE HILLS
SIERRA ESTRELLA
SOUTH MTS.
PHOENIX MTS.
MCDOWELL MTS.
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
SACATON MTS.
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
SALT RIVER
SANTA CRUZ RIVER
GILA RIVER
CAVE CREEK
CAREFREE
FOUNTAIN HILLS
SURPRISE
EL MIRAGE
SUN CITY WEST
SUN CITY
YOUNGTOWN
PEORIA
GLENDALE
LITCHFIELD PARK
PARADISE VALLEY
SCOTTSDALE
PHOENIX
GOODYEAR
AVONDALE
TOLLESON
TEMPE
MESA
GILBERT
CHANDLER
APACHE JUNCTION
QUEEN CREEK
SACATON
BUCKEYE
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S
T4S
T5S
R3W
R2W
R1W
R1E
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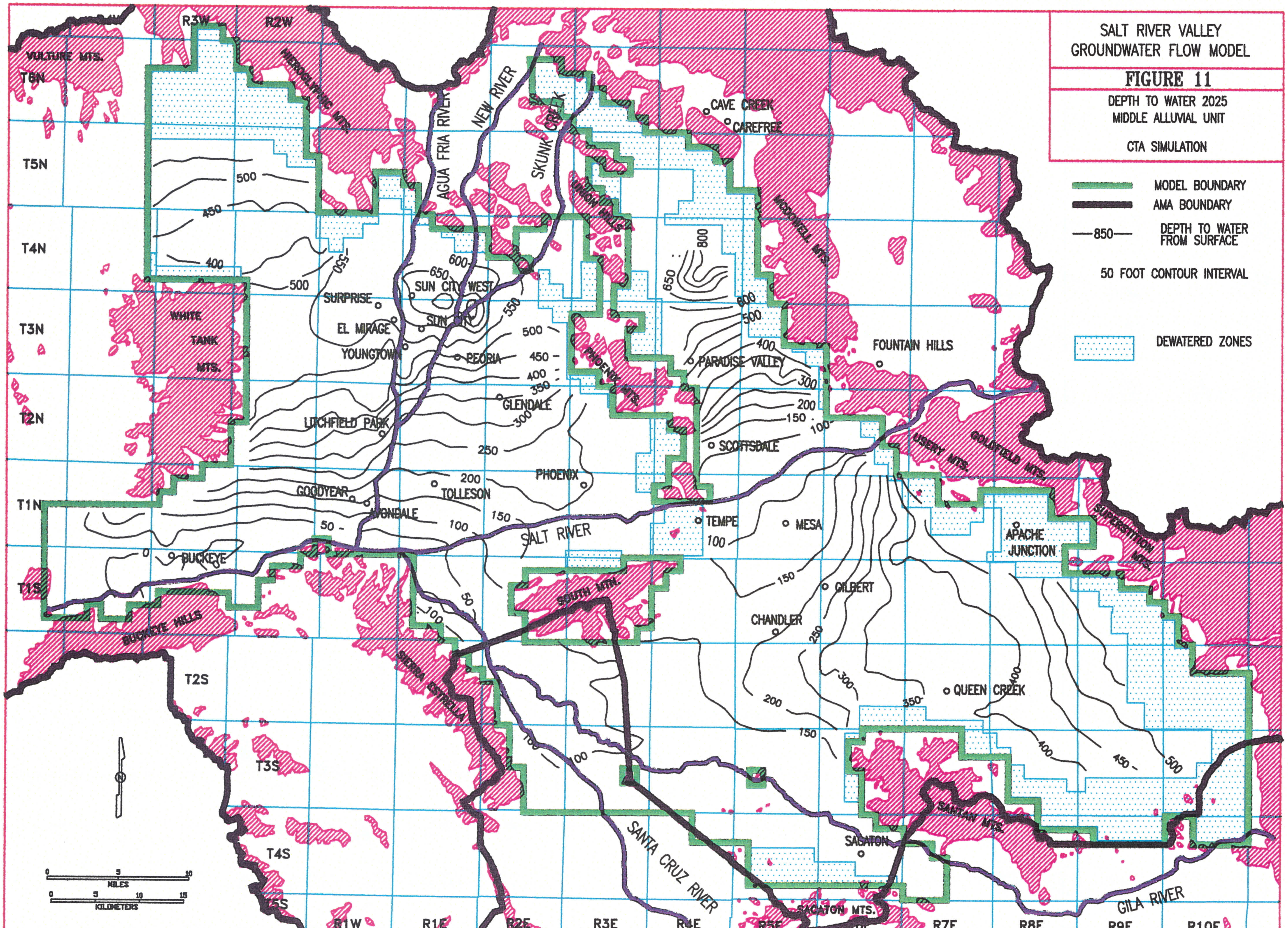
R3E
R4E
R5E
R6E
R7E
R8E
R9E
R10E
MILES
KILOMETERS


SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE 11
DEPTH TO WATER 2025
MIDDLE ALLUVIAL UNIT
CTA SIMULATION
MODEL BOUNDARY
AMA BOUNDARY
—850— DEPTH TO WATER FROM SURFACE
50 FOOT CONTOUR INTERVAL
DEWATERED ZONES
VULTURE MTS.
HIEROGLYPHIC MTS.
WHITE TANK MTS.
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
UNION HILLS
CAVE CREEK
CAREFREE
MCDOWELL MTS.
PHOENIX MTS.
FOUNTAIN HILLS
PARADISE VALLEY
SCOTTSDALE
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
APACHE JUNCTION
SURPRISE
EL MIRAGE
YOUNGTOWN
SUN CITY WEST
SUN CITY
PEORIA
GLENDALE
LITCHFIELD PARK
GOODYEAR
AVONDALE
TOLLESON
PHOENIX
BUCKEYE
SALT RIVER
TEMPE
MESA
GILBERT
CHANDLER
QUEEN CREEK
SOUTH MTS.
BUCKEYE HILLS
SIERRA ESTRELLA
SANTA CRUZ RIVER
SACATON
SACATON MTS.
SANTAN MTS.
GILA RIVER
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S
T4S
T5S
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R6E
R7E
R8E
R9E
R10E
MILES
KILOMETERS

Limitations and Error in the Calibrated Model

The error of any model analysis is important to consider when interpreting the results of future predictive model simulations. The analysis consisted of comparing the final calibrated water levels against measured water levels and calculating the mean absolute difference (error) per model cell and maximum difference per model layer in simulated water level versus measured water level and the standard deviation of the error for each model layer. Table 7 provides a statistical summary of the transient model accuracy.

Table 7

Absolute Average Difference in Head per Model Cell for Comparison of 1991 measured heads VS. 1991 model projected heads

LAYER	HEAD DIFFERENCE (measured vs. simulated)	NUMBER OF CELLS	ABSOLUTE AVG. DIFF. IN HEAD PER CELL (Ft)	STANDARD DEVIATION	MAXIMUM HEAD DIFF.
1	1991 meas. - sim.	1054	16.18	14.47	120.51
2	1991 meas. - sim.	1752	23.89	21.76	193.47
3	1991 meas. - sim.	2034	26.04	23.99	216.46

Limitations of the model should be recognized when evaluating the results of the model's ability to predict hydrologic conditions into the future. Like all tools used to project the future, it is imperfect, and some error is to be expected. The accuracy of the model predictions are limited by the data available to calculate future trends and the assumptions put into the model, as well as error in the original model construction. The model predictions should be viewed as an indication of future trends, but not as a precise measure of future groundwater conditions. The Salt River Valley Groundwater Flow Model is the result of five years of careful work on the part of Department hydrologists and is a good overall representation of the groundwater system of the Salt River Valley. Areas where improvements could be made to the model will be discussed later in the report.

The following groundwater flow modeling assumptions were made in order to simplify problems where data uncertainties exist or were necessary due to lack of data. Throughout the modeling process prior assumptions have been revised to reflect the current level of information known about the SRV study area. From the Phase II report on the Salt River Valley groundwater flow model (Corell and Corkhill, 1994) the limitations and assumptions that apply for this study are as follows:

- The SRV groundwater flow model is a regional model and is not intended to provide site-specific determinations of hydrologic conditions.

- Available groundwater level data adequately represent the flow system within the model domain. Water level distributions reflect the stresses (natural and artificial) imposed on the hydrologic system by pumpage, recharge, and fluxes along the boundaries of the model domain.

- Static water level measurements taken during the winter months are representative of the study area when the hydrologic system is considered to be the most quiescent.

- Wells perforated in multiple hydrogeologic units are withdrawing water from each hydrogeologic unit. The amount of water that each hydrogeologic unit contributes is dependent on the hydraulic conductivity and perforated saturated thickness of that hydrogeologic unit as compared to the hydraulic conductivity of the overall saturated thickness of the hydrogeologic unit(s) the well is perforated in. The precise proportion and distribution of water flowing into perforations in wells in this area are unknown. Therefore the amount of water each hydrogeologic unit contributes to the well was estimated using the flowing equation:

  $$(1) \qquad Q_n = \frac{K^n \times b^n}{T^t} \times Q^t \times 100$$

  And:

  $$(2) \qquad Q_n = Q_1 + Q^2 + Q^3 + \ldots + Q^n$$

  $$(3) \qquad T_t = K^1b^1 + K^2b^2 + K^3b^3 + \ldots + K^nb^n$$

  Where:
  Q_n = percentage of total well pumpage contributed by hydrogeologic unit n
  K_n = hydraulic conductivity of hydrogeologic unit n
  b_n = saturated perforated thickness of hydrogeologic unit n
  T_t = total transmissivity of saturated perforated hydrogeologic units
  Q_t = total pumpage from well

  Although equation (1) ignores well losses and the effects of partial penetration, due to the complexity and extent of the well field in the study area and the lack of any other data, this type of limiting and simplifying assumption was necessary.

- Hydraulic heads computed within each model cell represents the average head within the volume of that cell. Model cell size is critical to the accuracy of simulating the real groundwater system. Model cells in the SRV model are one square mile (640 acres) and vary in thickness from a few tens of feet to hundreds of feet.

- The boundary conditions for the model, based on historical conditions, may not accurately model the conditions into the future depending on the natural and artificial stresses put on the system.

CONCLUSIONS

The Current Trends Alternative (CTA) groundwater model scenario is a realistic projection based on demand and supply assumptions given to ADWR by the water providers or made by ADWR staff. The model was designed to be used as an exploration tool and future scenarios based on different assumptions may depict different results. This report does point to some potential problem areas. The hydrologic modeling results for the CTA indicate groundwater drawdowns throughout the West SRV and portions of the East SRV sub-basins. These drawdowns were most pronounced in the northern portion of the WSRV sub-basin around Sun City, Sun City West, and the growth areas of Peoria, Glendale and Surprise, and the northern portion of the ESRV in the north Scottsdale area. The simulated drawdowns in these areas would be more severe but the pumpage was under simulated as a result of the aquifers being dewatered near the basin margins and the groundwater demand not being moved to an "active" cell. When interpreting the results of any groundwater flow model used to project into the future the trends should be given more "weight" than the actual numbers.

In the WSRV under the CTA scenario most water suppliers were assumed to continue their groundwater use. Sun City and Sun City West Water Companies and the golf courses serving these fully subdivided communities have no requirements to reduce their dependency on groundwater. In the growth areas of Glendale, Peoria and Surprise, all new residential development will have to meet the Assured Water Supply rules, thus requiring more dependance on renewable water supplies. However, for the CTA scenario, the northern part of the WSRV was still assumed to be heavily dependant on groundwater, as the municipalities requested ADWR to assume for this scenario.

Bringing in renewable supplies such as CAP (and SRP where eligible) for new development, or even reducing groundwater use for existing development as Glendale has done, should partially alleviate the future drawdowns. Reliance on recharge credits or participation in a recharge project (i.e. GRUSP), or Groundwater Replenishment District membership, if the recharge occurs outside the area of drawdown, would not alleviate the high depth-to-water problem likely to be encountered in the future. The projected drawdown levels in the northern WSRV indicate that at some point beyond the year 2025 Assured Water Supplies may not be available in some regions because the depth to water will exceed 1000 feet. In this case, no new development will occur unless renewable supplies are brought in for direct use. Officials for many cities have indicated they expect a faster rate of growth than the projections used in this study. Considerable golf course development is also expected throughout the WSRV. In many cases, golf courses and other non-residential uses may not be subject to the Assured Water Supply rules in the service area of undesignated providers, hence significant users could still rely on groundwater, contributing to the projected drawdowns.

In the central portions of the WSRV, considerable growth is also projected within Litchfield Park Service Company's (LPSCO) service area, the south end of Citizens Agua Fria's service area, and The Arizona Water Company - White Tanks' service areas. LPSCO has a CAP allocation, but none of these providers have yet made the investment to bring renewable supplies into their service areas. The Groundwater Replenishment District, without recharge or in lieu use actually occurring in the WSRV, may not be a long term solution to the physical water supply problem.

In the southern portions of the West Salt River Valley, Avondale has much of the infrastructure in place or under development to utilize their CAP allotment and SRP entitlement. However, for Avondale, Goodyear, and Buckeye groundwater levels are not as much of a concern as is the quality of the available water.

In the ESRV, the north Scottsdale area was the only area that showed significant drawdowns. The projected depth to water by the year 2025 is over 800 feet in the MAU, suggesting the AWS cut off of 1000 feet to water would be reached before 100 years. As of 1991 there were areas in the LAU aquifer where the water table was 800 feet below land surface suggesting the 1000 foot cut off would be reached well in advance of 100 years. As noted earlier in this report, turf (golf course) demand from groundwater sources was assumed to remain the same through out the simulation. At the time of publication of this report the source of water for at least some of these turf facilities had switched to CAP water, thus lessening the potential drawdowns by a small percentage in some areas of north Scottsdale. The ESRV shows less drawdown than the WSRV because the waster providers and municipalities plan on using less groundwater to meet the demands and a better infrastructure exists to deliver renewable water supplies. Part of the infrastructure includes delivery systems that Salt River Project (SRP) and the Roosevelt Water Conservation District (RWCD) have developed to deliver water to various areas. The ESRV also has the benefit of several recharge projects along the Salt River, the most notable being the GRUSP site. This facility is located approximately where the Salt River enters the model area on the eastern boundary. The GRUSP site demonstrated a major influence in the ESRV, even though the amount of water recharge was reduced by half of the suggested recharge amount from 150,000 AF/Yr to 75,000 AF/Yr. The groundwater recharge from the GRUSP facility resulted in the water levels rising by over 250 feet in the Salt River area by the year 2025.

SRV water managers have a number of challenges to meet in their efforts to ensure a dependable and safe water supply for the orderly, sustainable, cost-effective, economic development of western Salt River Valley. The Department of Water Resources believes the information provided in this study provides a sound physical foundation for water resources planning. The Department is committed to assisting those efforts. The Hydrology Division, in cooperation with the Phoenix AMA, will continue to provide ongoing technical assistance to the communities. Conservation assistance and augmentation grant funds are also available to support water management activities throughout the AMA.

RECOMMENDATIONS

The Current Trends Alternative scenario is a reasonable representation of what will happen to the SRV groundwater system by the year 2025 using the projected water demand and supply data provided by the major water providers and municipalities. There are two sets of recommendations, one concerning management use of the model and the second set pertaining to improvements of the model.

Management Recommendations

This set of recommendations are intended to assist local planners in future water management issues.

1) Run a "high" demand, a "low" demand, and a renewable supply/recharge scenario. These scenarios would assist in determining the sensitivity of the projected groundwater levels to different stresses such as: changes in agricultural and municipal demands, urbanization patterns, different water supplies, and the addition of recharge projects.

2) Incorporate the SRV model into ADWR's planning efforts for the Third Management Plans. The model will be useful in informing decision makers about the implications of various water supply and demand assumptions on the groundwater system.

3) Utilize the SRV Model to assist in the Assured Water Supply Program. The model will again be useful in informing decision makers about the implications of various water supply and demand assumptions on the groundwater system. It will also be useful as a screening tool in evaluating the physical aspects of an AWS applications and in identifying areas of concern to the Department.

4) Adding projected population growth to the Apache Junction WPA, preferably by using population projections from Pinal County or by applying the rate of population growth in east Mesa to the Apache Junction WPA.

5) Incorporating in-lieu water for the projections after 1992, which would reduce the agricultural pumping in some irrigation districts. In-lieu water is a renewable water supply (i.e. CAP water) that is used for agricultural purposes instead of groundwater.

6) Continue to update the SRV model with newly available geologic and hydrologic data to improve the ability of the model to represent the groundwater system and to make the model results as realistic as possible.

Model Improvement Recommendations

1) Incorporate subsidence modeling into the SRV model to more accurately represent the subsidence that is occurring in the model area. This would allow the model to better simulate the reduction of storage in areas that have subsided. The subsidence modeling capability would also assist in predicting were subsidence is going to occur, giving planners the ability to anticipate the associated infrastructure damage that may occur.

2) Updating the geological information used in the model would improve the accuracy of the model in certain areas. This is especially true in areas where data was scarce when the information was compiled for the model or where bedrock has been found to be at more shallow depths than first indicated.

3) Upgrading the river simulation module currently in the model to the Prudic module, an improved river modeling module for MODFLOW. The Prudic module was not available at the time the SRV model was built. This module allows better simulating streamflow in the rivers, and would assist in being able to more accurately representing recharge or discharge associated with the Salt and Gila Rivers.

4) Better define the agricultural data to more accurately model the agricultural pumping, urbanization, and agricultural recharge.

5). Continue the effort to develop a more efficient and user-friendly GIS "front end" to analyze alternative projection scenarios and prepare model data inputs.

Future Uses of the SRV Model

Future uses of the model include work on the Third Management Plan, assisting with Assured Water Supply program, and analyzing different planning scenarios. Besides being an excellent means to simulate groundwater conditions, the associated database and programs provide useful tools for the analysis, and interpretation of a wide range of information that will be needed for the Third Management Plan. For the Assured Water Supply program the model will be used to assist in determining water availability. The SRV model has the advantage of being able to handle numerous different variables at one time, however, it should be remembered that the model is intended for regional, and not site specific analysis. Different demand and supply source scenarios are planned for the future which will provide a better understanding concerning the sensitivity of the groundwater flow system to the different demands and stresses.

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APPENDIX I - SRV Groundwater Flow Model

Numerical Model

General Approach

The regional numerical groundwater flow model for the Salt River Valley (SRV) developed by Corell and Corkhill (1994) is approximately 2,240 mi^2 in size and incorporates portions of both the East and West Salt River Valley sub-basins (Figure 1.). The model was calibrated for steady-state hydrologic conditions (ie, circa 1900) and transient conditions between 1983 and 1991. The model is quasi-three-dimensional and contains three layers that correspond to the alluvial hydrogeologic units within the SRV.

The model was used to simulate hydrologic conditions between 1989 and 2025 in 5-year increment starting with 1995 and ending with 2025. Projected water supply and demand for both M & I and agricultural sectors were estimated for each 5-year increments.

General Features of the Model

Model Grid

The SRV model grid consists of 62 rows and 90 columns with three layers and is oriented with the Arizona state baseline and principal meridian. Model cells are one mile in length and width and are closely aligned with the local Township-Range-Section survey grid in most locations. The active model domain encompasses 2,240 mi^2 and contains most of the East and West SRV sub-basins of the Phoenix AMA, and the northern- most portion of Maricopa-Stanfield sub-basin of the Pinal AMA.

Model Layers and Aquifer Conditions

Three model layers were used to represent the three hydrogeologic units that have been identified within the Salt River Valley. The uppermost layer, Layer 1, corresponds to the Upper Alluvial Unit (UAU) which is modeled as an unconfined aquifer. The middle layer, Layer 2, corresponds to the Middle Alluvial Unit (MAU) and is modeled as a confined/unconfined aquifer. This layer is modeled as confined when the overlying UAU is saturated and unconfined when the UAU is dewatered. The lowermost layer, Layer 3, corresponds to the Lower Alluvial

Unit (LAU) and is also modeled as a confined/unconfined aquifer. The layer is modeled as confined where the overlying MAU is saturated and unconfined where the MAU is dewatered. The Red Unit which occurs in east Phoenix and Scottsdale is included in the LAU due to its similar hydrologic properties and limited areal extent. Near the basin margins, the bottom of Layer 3 corresponds to the geologic contact of the basin-fill and crystalline basement bedrock. Towards the basin centers where the basin-fill deposits are very thick, the bottom of Layer 3 parallels land surface elevations with a maximum depth of 3,000 feet below land surface. The maximum thickness of 3,000 feet for the lowermost layer was selected in part, because there are no pumping wells deeper than 3000 feet in the model study area (Corkhill and others, 1993).

For a more detailed discussion regarding the modeling of the hydrogeologic units, refer to Corell and Corkhill (1994).

Boundary Conditions

The selection of proper model boundary conditions is essential to the accuracy of the model. Boundary cell types define the hydrologic conditions along the model borders. There are two fundamental types of model cells; active and inactive. Inactive model cells (ie, no-flow cells) are those for which no groundwater flow into or out of the cell is permitted. No-flow cells correspond to either hydrologic bedrock (e.g., Phoenix Mountains, White Tank Mountains) or areas where groundwater flow is parallel to impermeable boundaries.

There are two types of active cells; variable head and constant head. Variable head cells permit the water-level elevation in the cell to fluctuate with time. These cells comprise the active simulated region within the model domain. Constant head cells fix the water-level elevation at a constant specified elevation, but allow the flux into or out of the cell to change in response to changing hydrologic conditions.

Constant flux underflow conditions were simulated along the southern model boundary, and at certain locations along the eastern and northern boundaries of the model (Corell and Corkhill, 1994). Constant flux conditions were simulated at these locations either because invariant underflow and mountain front recharge conditions exist, or boundary fluxes were estimated as constant from previous model studies (Wickham and Corkhill, 1989).

Water Levels

Water levels were required for both the steady-state and transient-state calibrations. Water levels representing pre-development era (ie, circa 1900) were developed and used for the steady-state calibration (Corell and Corkhill, 1994).

Initial (ie, winter 1983) and final (ie, winter 1991) water levels were required for the transient calibration. Hydrogeologic unit-specific water level elevation maps were created for each model layer. Corell and Corkhill (1994) document and discuss the method of obtaining representative water levels for each of the hydrogeologic units within the SRV. The final water level elevation maps (1991) were used as targets to determine the success of the transient calibration.

Final water levels from the calibrated transient-state model were used as initial water levels for the CTA model run. This was done to ensure that the hydraulic properties and fluxes are internally consistent.

Aquifer Parameters

Initial hydraulic conductivity estimates were developed using aquifer test data from groundwater contamination site studies, specific capacity data from Ground Water Site Inventory (GWSI) database and other sources, recovery test data from the Salt River Project (SRP), and particle size data from the U.S. Geological Survey (Corell and Corkhill, 1994). Hydraulic conductivity values were adjusted during the steady-state calibration.

Storage estimates (specific yield and storage coefficient) were also obtained from aquifer test data and other sources including published information regarding reasonable estimates dependant upon the geologic material type (Corell and Corkhill, 1994). These initial estimates were adjusted during the transient-state calibration. Refer to Corell and Corkhill (1994) for the final calibrated distribution of aquifer parameters.

Canals and Rivers

Groundwater interaction with both rivers and canals was simulated in the SRV model. Recharge simulated from primary rivers included the Gila, Salt, Agua Fria, Skunk Creek, New

River, and Queen Creek. Estimates of deep percolation recharge from these rivers were estimated based upon gaging data and infiltration rate estimates. However, the Salt River downstream of the 91st Avenue Waste Water Treatment Plant (WWTP) was simulated as a perennial river due to the constant discharge of effluent into the river bottom. Refer to Corkhill and others (1993) for a more detailed discussion.

Recharge simulated from primary canals included all of the SRP canal system (e.g., Arizona, Grand, South, Tempe, Consolidated), Roosevelt Irrigation District canal, Buckeye Irrigation District canals, Maricopa Water District's Beardsley Canal, Roosevelt Water Conservation District Canal and portions of the San Carlos Irrigation Project canals. Estimates of deep percolation recharge from these canals was estimated assuming a representative infiltration rate based on canal lining conditions and wetted area. Refer to Corkhill and others (1993) for a more detailed discussion.

Vertical Leakance Between Layers

Vertical leakance of water between Layers 1 and 2, and Layers 2 and 3 was modeled using the VCONT option. MODFLOW requires VCONT to be calculated outside of the model and then input as an array. The VCONT parameter was subsequently adjusted during the steady-state calibration of the model. Refer to Corell and Corkhill (1994) for the final distribution of this parameter.

APPENDIX II - Assumptions for the Current Trends Alternative Scenario

The Current Trends Alternative (CTA) reflects to a large degree the growth patterns and the sources of supply as seen by the municipalities and irrigation districts in 1993 and 1994. This information is the result of numerous meetings conducted by ADWR with the major water users and suppliers to determine the areas effected and the projected supplies of water needed to meet future demands. Once the initial information was implemented into the model follow up meetings were held to verify that the model accurately reflected the municipalities and irrigation districts future plans.

In order to understand the groundwater model and its results, it is necessary to understand the assumptions about future water use and water supply. The model was used to simulate hydrologic conditions between 1991 and 2025. Projected water supply and demand for municipal, industrial, and agricultural sectors was estimated for 5-year increments between 1995 and 2025. The following is a list of general assumptions that apply to the CTA scenario.

General Assumptions

Overall

- 1991 was assumed to be a typical use and supply year and was used as the last period of measured data. Most cities and irrigations districts felt this was a reasonable assumption during discussions, except for the Salt River Project (see assumptions under Irrigation Districts / Providers).

Municipal

- Municipal growth within Maricopa County will be assumed to follow Maricopa Association of Government (MAG) projections made in March, 1993. At the time of the Current Trends Alternative model run, projected population data was not available within the Department for portions of Pinal County within the Phoenix AMA. For these regions any municipal groundwater pumping remained constant at 1991 levels.

- Municipal water demand rates held constant at 1991 levels. The demand rates were calculated by using the housing unit projections from MAG times a water use rate (gallon per household unit per day). The gallon per household unit per day (GPHUD) was calculated by taking the total water use (obtained from the providers 1991 annual water withdrawals and use reports) divided by the total housing units for 1991. For areas of future growth not currently within a large providers service area the following assumptions were made: 1) for areas that will be a part of a Water Planning Area (WPA) associated with a municipality or larger water provider in the future the provider's projected GPHUD was used; 2) for other areas the Maricopa County averages for demographic data and 141 GPCD was used (the minimum for a new large provider with greater than 5% non-residential use).

- Municipalities will use sources of supply as indicated in their discussion with ADWR. Sources of supply were SRP surface water and groundwater, only groundwater, other surface water, effluent, and CAP water. Some cities use or intend to use CAP water and some do not. The study area was broken into 68 different Water Planning Areas (WPA) based on land ownership, source of supply, and proportions of supply sources. These areas reflected various mixes of groundwater, surface water and CAP use. The various assumptions per WPA are listed after this section.

- Municipal wells that were in service in 1991 will remain in service unless alternative plans were identified in discussions with municipalities or other water suppliers. New wells were added in locations specified by the municipalities as needed to supply additional groundwater demands, or if no information was supplied, demand was equally spread across each model cell for a specific WPA.

- Urban irrigation was held constant at 1991 levels, except for certain providers, noted below in the Irrigation / Providers section.

Agricultural

- The number of acres of actual irrigated land will remain constant at 1991 levels except for farmland projected to be urbanized.

- Farmland urbanizes when housing density reaches an average of one house per acre within a model cell (640 houses per square mile).

- Farming irrigation will continue at 1991 levels of efficiency. This is consistent with keeping 1991 GPHUD constant for municipalities. Although the ADWR management plans reduce water allotments based on assumed increases in efficiency, there are a sufficient number of flex credits built up that an increase in efficiency would be required on very few farms.

- Recharge from agricultural use will not cease in the year that the land is urbanized, but would continue for some time as the vadose zone slowly drains downward to the water table.

- Pumping on the Gila River Indian Reservation and the Salt River Indian Reservation was held constant at estimated 1991 pumping levels (Corkhill and others, 1993).

Irrigation Districts / Providers

- 1991 pumpage and source mixtures were held constant with the following exceptions.

- The 1991 pumpage for the Salt River Project (SRP) was abnormally low. For this reason the model projections used the historic average groundwater pumpage for 1975 to 1993 of 142,000 acre-feet per year (AF/Yr) as being more representative of long term conditions. SRP provided specific volumes, from specific wells, to meet this demand.

- When agricultural lands urbanize within the SRP service areas the SRP wells continue to pump at the same capacity. This assumes that SRP pumpage will convert from agricultural to municipal uses.

- Pumping from Roosevelt Water Conversation District (RWCD) and Roosevelt Irrigation District (RID) does not decrease with urbanization. The pumping at RWCD is assumed to convert to urban flood irrigation. Per information from RID personnel the urbanized wells would supply additional irrigation water to other lands which hold water rights and could use additional water. For the other irrigation districts the agricultural pumping was turned off when the agricultural lands were urbanized.

- The pumping from SRP, or RWCD was not altered to account for the In-Lieu CAP recharge program.

Recharge

- Recharge projects: only currently permitted, as of 1993, (or nearly permitted) recharge projects were included in the model. For the Current Trends Alternative Scenario it was assumed the recharge facilities would renew their permits through the time period of the simulation (1995 to 2025). Recharge volumes used in the model are as described in the permit for the facility, with the exception of GRUSP. The recharge projects modeled and the actual amounts of recharge used for the CTA scenario can be found in Table 5.

- Natural recharge from the Salt River and Gila River were held constant at 127,500 AF/Yr, the average recharge from the period of 1964 to 1991. This recharge includes very high volumes during this period which saw an unusual number of large floods. The high volumes could skew the amount of recharge especially for longer model runs. A average recharge rate from a longer period of time is recommended for future use, especially for scenarios projecting further out in time.

Turf Facilities (Golf Courses) and Industrial

- If a turf facility was served wholly or in part by a municipal provider in 1991, this demand was included in the calculation of the municipal GPHUD. However, this did not include the new facilities that would be built in response to increased population. This additional demand was assumed to be met by municipal providers. The actual amount of water demand for the new turf facilities was calculated per WPA using four different scenario's that will be explained in more detail in the next session. As noted earlier in this report, turf (golf course) demand from groundwater sources in the north Scottsdale area (WPAs 31 and 32) was assumed to remain the same through out the simulation. At the time of publication of this report the source of water for at least some of these turf facilities had switched to CAP water, thus lessening the potential drawdowns by a small percentage in some areas of north Scottsdale

- Current turf ratios (acres of golf course per housing unit) (3,000 housing units per golf course) were maintained throughout the projection period, except for built out areas. Where appropriate, new turf facilities were added to areas with no golf courses as urbanization occurred.

- Non-turf industrial water use is held at 1991 levels.

- The amount and location of wells designated for turf in 1991 remained constant throughout the projections.

Specific WPA Assumptions

The assumptions for the individual WPA's were arrived at in cooperation with larger irrigation districts and most of the municipalities in the Phoenix AMA. The information gathered included supply sources for the municipal projected water demands, and location of future groundwater supply wells if known. A water use rate per housing unit per day (GPHUD) was calculated by the Phoenix AMA for each WPA to determine the water demand. Added to the projected municipal water demands was a demand for the increase in the number of golf courses (turf facilities) not served by municipal providers as population grows. Projected turf demand for WPAs was calculated using the 1991 gallons per housing unit per day (GPHUD) demand for golf courses times the projected increase in population for each WPA. If the future turf demand was not expected to follow current trends with in a WPA, the WPA was given a high, low, or medium turf GPHUD equivalent depending on the expected characteristics of the WPA. The high turf demand (186 gphud) was based on retirement community characteristics, the low demand (108 gphud) was based on AMA-wide additional per capita turf demand for post-1984 growth, and the medium (132 gphud) was near the average of the two. Master plan communities that were confident of how many additional golf courses would be on-line by buildout were given a lump sum of additional turf demand based on the post-1984 AMA average demand for new 18-hole courses. This lump sum was then divided by year 2000 population for the WPA to get the GPHUD equivalent. No WPAs were given additional industrial demand for 1995 other than for existing golf courses that have come on line since 1990. The specific assumptions concerning water sources for each WPA can be found in Table AII-1. A summation of the assumptions used per each WPA is listed after Table AII-1.

Table AII-1 is a breakdown of the assumed water supply source for each WPA. Almost all of the following information was provided by the individual municipalities and water suppliers. The corresponding physical location of the WPA's can be found on Figure 8. In the WPA columns "INMOD" and "OUTMOD" refer to the portion of the WPA inside and outside the model area respectively. The water demand of the WPA's outside of the model are meet by water providers inside the model or by local groundwater which is not included in the groundwater model. The water sources used for the CTA scenario are groundwater (GW), surface water (SW), surface water supplied by Salt River Project (SRP SW), groundwater supplied by Salt River Project (SRP GW), and water supplied from CAP. If a WPA used CAP water the specified percentage of its demand was supplied by CAP until the CAP allotment was reached. Any added demand above the limit was assumed to be supplied by groundwater.

Table AII-1

ASSUMPTIONS BY WPA for WATER SOURCES

SOURCES (%)

WPA	WPA #	GW	SW	SRP SW	SRP GW	CAP	COMMENTS
Sun City West	1	100					
Sun City	6	100					
Other Sun City	2	100					
Az Water Co. White Tanks	3	100					
Citizens Agua Fria	4	100					
El Mirage	5	100					
Luke Air Force Base	7	100					
Avondale (INMOD)	8	100					
Avondale (OUTMOD)	48	100					Supplied from WPA 8
Avondale SRP	68			70	30		
Glendale (INMOD)	10	15				85	27,000 AF CAP Limit*
Glendale (OUTMOD)	11	15				85	Supplied from WPA 10
Glendale SRP	9			85	15		
Glendale Outside Survive Area	12	100					
Goodyear (INMOD)	13	100					
Goodyear (OUTMOD)	59	100					Supplied from WPA 13
Goodyear - LPSCO	55	100					
LPSCO	14	100					
North County	15	100					
West Central County (INMOD)	61	100					
West Central County (OUTMOD)	62	100					
Surprise	62	100					
Tolleson	17			70	30		
West Maricopa Combine	18	100					
Youngtown	19	100					

* CAP Limit refers to the CAP allotment as of 1991 for the municipality, irrigation district, or water company referred to. After this limit was reached additional demand was assumed to be met by groundwater.

Table AII-1
(continued)

SOURCES (%)

WPA	WPA #	GW	SW	SRP SW	SRP GW	CAP	COMMENTS
Hassayampa Basin	20	100					
Rainbow Valley	21	100					
Gilbert	23					100	5,000 AF CAP Limit* w/ WPA 27
Gilbert - RWCD	27					100	5,000 AF CAP Limit* w/ WPA 23
Gilbert - SRP	22			70	30		
Cave Creek	24		100				
Cave Creek (OUTMOD)	58	100					
Gila River	25	100					
Queen Creek	26	100					
Apache Junction	28					100	1,500 AF CAP Limit*
Ground Water (INMOD)	29	100					
Ground Water (OUTMOD)	30	100					
Scottsdale (INMOD)	31	20				80	64,000 AF CAP Limit*
Scottsdale (OUTMOD)	32	20				80	Supplied from WPA 31
Scottsdale - SRP	66			70	30		
Guadalupe	33					100	
Tempe	35					100	4,400 AF CAP Limit*
Tempe - SRP	34			100			
Chandler	36					100	6,250 AF CAP Limit* w/ WPA 38
Chandler - RWCD	38					100	6,250 AF CAP Limit* w/ WPA 36
Chandler - SRP	37			60	40		
Mesa	39	10				90	35,000 AF CAP Limit* w/ WPA 40
Mesa - RWCD	40	10				90	35,000 AF CAP Limit* w/ WPA 39
Mesa - SRP	41			70	30		
Carefree (INMOD)	42	100					
Carefree (OUTMOD)	43	100					

* CAP Limit refers to the CAP allotment as of 1991 for the municipality, irrigation district, or water company referred to. After this limit was reached additional demand was assumed to be met by groundwater.

Table AII-1
(continued)

SOURCES (%)

WPA	WPA #	GW	SW	SRP SW	SRP GW	CAP	COMMENTS
Peoria	44	100					
Peoria - SRP	63			70	30		
Buckeye (INMOD)	45	100					
Buckeye (OUTMOD)	46	100					
Paradise Valley (INMOD)	47	100					
Paradise Valley (OUTMOD)	49	100					Supplied from WPA 47
Phoenix - Area I (INMOD)	50	10	90				100% GW for 1995
Phoenix - Area I (OUTMOD)	51	10	90				Supplied from WPA 50
Phoenix - Area 2 (INMOD)	52	100					
Phoenix - Area 2 (OUTMOD)	53	100					Supplied from WPA 52
Phoenix - Area 3 (INMOD)	54					100	170,000 AF CAP Limit*
Phoenix - Area 3 (OUTMOD)	64					100	Supplied from WPA 54.
Phoenix - SRP	65			70	30		
Fountain Hills	57					100	
RWCD (outside of MPAs)	60	80	20				
Sun Lakes	67	100					
Maricopa East	70	100					

* CAP Limit refers to the CAP allotment as of 1991 for the municipality, irrigation district, or water company referred to. After this limit was reached additional demand was assumed to be met by groundwater.

The following is a list of the specific assumptions for each WPA that was used in the CTA scenario. Municipal gallons per housing unit or the GPHUD refers to the historic water use for each WPA. The industrial-turf gallons per housing unit is the historic water use for turf facilities used to calculate the water demand for projected golf courses. Refer to Figure 8 for geographical location of the WPAs.

Sun City West, WPA 1

- The municipal demand supplied by groundwater.
- When the demand is over the amount pumped in 1991 the first 1,000 acre-feet per year (AF/Yr) will be meet by a well located in T4N R1E section 28, the next 1,000 AF/Yr was attributed to a well in T4N R1E section 22. Any demand over the 2,000 AF/Yr was spread evenly over the WPA. (Note: both wells in the Peoria WPA)
- Municipal gallons per housing unit = 371
- Industrial-turf gallons per housing unit = 21.4

Other Sun City Water Company, WPA 2

- The municipal demand supplied by groundwater.
- Demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 991
- Industrial-turf gallons per housing unit = 490

Sun City Water Company - Sun City, WPA 6

- The municipal demand supplied by groundwater.
- The first 1,000 AF/Yr above the 1991 pumping levels was attributed to a well in T4N R1E section 32, anything over this amount was spread over the WPA.
- Municipal gallons per housing unit = 397
- Industrial-turf gallons per housing unit = 14

Arizona Water Company White Tanks, WPA 3

- The municipal demand supplied by groundwater.
- Demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 329
- Industrial-turf gallons per housing unit = 0

Citizens Agua Fria, WPA 4

- The municipal demand supplied by groundwater.
- Demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 374
- Industrial-turf gallons per housing unit = 190

El Mirage, WPA 5

- The municipal demand supplied by groundwater.
- Demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 329
- Industrial-turf gallons per housing unit = 52

Luke Air Force Base, WPA 7

- The municipal demand supplied by groundwater.
- Demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 303
- Industrial-turf gallons per housing unit = 0

Avondale, WPA 8 (in model) and WPA 48 (outside of model)

- The municipal demand supplied by groundwater. All of the municipal demand in WPA 48 is supplied within WPA 8.
- Demand over the 1991 levels was un-evenly distributed between two model cells adjacent to the new Star-Tek recharge facility west side of the Agua Fria River, 75% T2N R1W section 36 and 25% T2N R1W section 35. The un-even distribution was due to numerical instabilities within the model.
- Municipal gallons per housing unit = 575
- Industrial-turf gallons per housing unit = 54

Avondale - SRP, WPA 68

- The municipal demand supplied by 70% SRP surface water and 30% SRP groundwater.
- Municipal gallons per housing unit = 575
- Industrial-turf gallons per housing unit = 54

Glendale - SRP, WPA 9

- The municipal demand supplied by 85% SRP surface water and 15% SRP groundwater.
- Municipal gallons per housing unit = 493
- Industrial-turf gallons per housing unit = 12

Glendale, WPA 10 (in model) and WPA 11 (outside of model)

- The municipal demand supplied by 85% from CAP and 15% from groundwater. When the CAP limit of 27,000 AF\Yr is reached the remaining demand will be supplied completely from groundwater.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 493
- Industrial-turf gallons per housing unit = 12

Glendale Outside Service Area, WPA 12

- The municipal demand supplied by groundwater.
- Demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 493
- Industrial-turf gallons per housing unit = 12

Goodyear, WPA 13 (in model) and WPA 59 (outside of model)

- The municipal demand supplied by groundwater. All of the municipal demand in WPA 59 is supplied within WPA 13.
- Demand over the 1991 levels was distributed evenly between five sections near their current Well Field #6. The location of the five sections are: T2N R1E section 33 (GOODYEAR LIPSCO), T2N R1E section 34 (GOODYEAR LIPSCO), T1N R1E section 3, T1N R1E section 4, T1N R1E section 9, and T1N R1E section 16.
- Municipal gallons per housing unit = 798
- Industrial-turf gallons per housing unit = 209

Goodyear - LIPSCO, WPA 55

- The municipal demand supplied by groundwater.
- Demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 1578
- Industrial-turf gallons per housing unit = 201

Litchfield Park Service Company, WPA 14

- The municipal demand supplied by groundwater.
- The first 3,000 AF/Yr above the 1991 pumping levels was attributed to a proposed well field in T2N R1W section 23; the second 3,000 AF/Yr provide from a proposed well field in T2N R1W section 14; and the next 3,000 AF/Yr was attributed to the T2N R1W section 11 (GLENDALE WPA). Any demand over the 9,000 AF/Yr was spread evenly over the WPA.
- Municipal gallons per housing unit = 1202
- Industrial-turf gallons per housing unit = 239

North County, WPA 15

- The municipal demand supplied by groundwater.
- Demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 283
- Industrial-turf gallons per housing unit = 132

West Central, WPA 61 (in model) and WPA 62 (outside of model)

- The municipal demand supplied by groundwater.
- Demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 230
- Industrial-turf gallons per housing unit = 108

Suprise, WPA 16

- The municipal demand supplied by groundwater.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 388
- Industrial-turf gallons per housing unit = 283

Tolleson, WPA 17

- The municipal demand supplied by 70% SRP surface water and 30% SRP groundwater.
- Municipal gallons per housing unit = 1137
- Industrial-turf gallons per housing unit = 216

West Maricopa Combine, WPA 18

- The municipal demand supplied by groundwater.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 290
- Industrial-turf gallons per housing unit = 0

Youngtown, WPA 19

- The municipal demand supplied by groundwater.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 493
- Industrial-turf gallons per housing unit = 101

Hassayampa Basin, WPA 20

- The municipal demand supplied by groundwater.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 277
- Industrial-turf gallons per housing unit = 130

Rainbow Valley, WPA 21

- The municipal demand supplied by groundwater.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 382
- Industrial-turf gallons per housing unit = 179

Gilbert - SRP, WPA 22

- The municipal demand supplied by 70% SRP surface water and 30% SRP groundwater.
- Municipal gallons per housing unit = 626
- Industrial-turf gallons per housing unit = 179

Gilbert, WPA 23 and Gilbert - RWCD, WPA 27

- The municipal demand supplied by 100% from CAP. When the CAP limit of 5,000 AF\Yr is reached, the combined demand from both WPA's, the remaining demand will be supplied completely from groundwater.
- Groundwater demand over the CAP limit and above 1991 levels was spread evenly over the WPAs.
- Municipal gallons per housing unit = 626
- Industrial-turf gallons per housing unit = 179

Cave Creek, WPA 24

- The municipal demand supplied 100% by surface water.
- Municipal gallons per housing unit = 284
- Industrial-turf gallons per housing unit = 137

Gila River, WPA 25

- The municipal demand supplied by groundwater.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 398
- Industrial-turf gallons per housing unit = 186

Queen Creek, WPA 26

- The municipal demand supplied by groundwater.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 693
- Industrial-turf gallons per housing unit = 359

Apache Junction, WPA 28

- The municipal demand supplied by 100% from CAP. When the CAP limit of 1,500 AF\Yr is reached, the remaining demand will be supplied completely from groundwater. Population projections were not available at the time of this scenario, therefore the 1991 pumping demand remained constant.
- Groundwater demand over the CAP limit and above 1991 municipal groundwater pumping levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 1991 pumping was kept constant
- Industrial-turf gallons per housing unit =

Ground Water (in model area), WPA 29

- The municipal demand supplied by groundwater.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 398
- Industrial-turf gallons per housing unit = 186

Ground Water (outside of model area), WPA 30

- The municipal demand supplied by groundwater.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 398
- Industrial-turf gallons per housing unit = 186

Scottsdale, WPA 31 (in model) and WPA 32 (outside of model)

- The municipal demand supplied by 80% from CAP and 20% from groundwater. When the CAP limit of 64,000 AF\Yr is reached, the remaining demand will be supplied completely from groundwater. All of the municipal demand for WPA 32 is supplied within WPA 31.
- Groundwater demand over the CAP limit and above 1991 municipal groundwater pumping levels was spread evenly over WPA 31.
- Municipal gallons per housing unit = 591
- Industrial-turf gallons per housing unit = 50

Scottsdale - SRP, WPA 66

- The municipal demand supplied by 70% SRP surface water and 30% SRP groundwater.
- Municipal gallons per housing unit = 591
- Industrial-turf gallons per housing unit = 50

Guadalupe, WPA 33

- The municipal demand supplied by 100% from CAP. When the CAP limit is reached, the remaining demand will be supplied completely from groundwater.
- Groundwater demand over the CAP limit and above 1991 municipal groundwater pumping levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 620
- Industrial-turf gallons per housing unit = 40

Tempe - SRP, WPA 34

- The municipal demand supplied by 100% SRP surface water.
- Municipal gallons per housing unit = 620
- Industrial-turf gallons per housing unit = 40

Tempe, WPA 35

- The municipal demand supplied by 100% from CAP. When the CAP limit of 4,400 AF\Yr is reached, the remaining demand will be supplied completely from groundwater.
- Groundwater demand over the CAP limit and above 1991 municipal groundwater pumping levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 620
- Industrial-turf gallons per housing unit = 40

Chandler, WPA 36 and Chandler - RWCD, WPA 38

- The municipal demand supplied by 100% from CAP. When the CAP limit of 6,250 AF\Yr is reached, the combined demand from both WPA's, the remaining demand will be supplied completely from groundwater.
- Groundwater demand over the CAP limit and above 1991 levels was spread evenly over the WPAs.
- Municipal gallons per housing unit = 610
- Industrial-turf gallons per housing unit = 73

Chandler - SRP, WPA 37

- The municipal demand supplied by 60% SRP surface water and 40% SRP groundwater.
- Municipal gallons per housing unit = 610
- Industrial-turf gallons per housing unit = 73

Mesa, WPA 39 and Mesa - RWCD, WPA 40

- The municipal demand supplied by 90% from CAP and 10% from groundwater. When the CAP limit of 35,000 AF\Yr is reached, the combined demand from both WPA's, the remaining demand will be supplied completely from groundwater.
- Groundwater demand over the CAP limit and above 1991 levels was spread evenly over the WPAs.
- Municipal gallons per housing unit = 378
- Industrial-turf gallons per housing unit = 30

Mesa - SRP, WPA 41

- The municipal demand supplied by 70% SRP surface water and 30% SRP groundwater.
- Municipal gallons per housing unit = 378
- Industrial-turf gallons per housing unit = 30

Carefree, WPA 42 (in model) and WPA 43 (outside of model)

- The municipal demand supplied by groundwater.
- Demand over the 1991 levels was evenly distributed for each of the WPAs.
- Municipal gallons per housing unit = 1017
- Industrial-turf gallons per housing unit = 215

Peoria, WPA 44

- The municipal demand supplied by groundwater.
- Demand over the 1991 levels was distributed evenly to six new wells; T3N R1E section 1, T3N R1E section 3, T3N R1E section 22 (PEORIA - SRP), T3N R1E section 25 (PEORIA - SRP), T3N R1E section 31, and T4N R1E section 30.
- Municipal gallons per housing unit = 473
- Industrial-turf gallons per housing unit = 114

Peoria - SRP, WPA 63

- The municipal demand supplied by 70% SRP surface water and 30% SRP groundwater.
- Municipal gallons per housing unit = 473
- Industrial-turf gallons per housing unit = 114

Buckeye, WPA 45 (in model) and WPA 46 (outside of model)

- The municipal demand supplied by groundwater.
- Demand over the 1991 levels was evenly distributed for each of the WPAs.
- Municipal gallons per housing unit = 424
- Industrial-turf gallons per housing unit = 0

Paradise Valley, WPA 47 (in model) and WPA 49 (outside of model)

- The municipal demand supplied by groundwater. All municipal demand for WPA 49 is supplied by WPA 47.
- Demand over the 1991 levels was evenly distributed over WPA 47.
- Municipal gallons per housing unit = 2134
- Industrial-turf gallons per housing unit = 0

Phoenix - Area I, WPA 50 (in model) and WPA 51 (outside of model)

- The municipal demand for 1995 was 100% groundwater, for all other projections (year 2000 to 2025) the supply was 90% surface water and 10% groundwater. All demand for WPA 51 supplied by WPA 50.
- Groundwater demand over the 1991 levels for WPA 50 was evenly distributed over WPA 50.
- Municipal gallons per housing unit = 570
- Industrial-turf gallons per housing unit = 230

Phoenix - Area II, WPA 52 (in model) and WPA 53 (outside of model)

- The municipal demand was supplied by 100% groundwater. All demand for WPA 53 supplied by WPA 52.
- Groundwater demand over the 1991 levels for WPA 52 was evenly distributed over WPA 52.
- Municipal gallons per housing unit = 570
- Industrial-turf gallons per housing unit = 230

Phoenix - Area III, WPA 54 (in model) and WPA 64 (out of model)

- The municipal demand supplied by 100% from CAP. When the CAP limit of 170,000 AF\Yr is reached, the combined demand from both WPA's, the remaining demand will be supplied completely from groundwater.
- Groundwater demand for both WPA's over the CAP limit and above 1991 levels was spread evenly over WPA 54.
- Municipal gallons per housing unit = 570
- Industrial-turf gallons per housing unit = 230

Phoenix - SRP, WPA 65

- The municipal demand supplied by 70% SRP surface water and 30% SRP groundwater.
- Municipal gallons per housing unit = 570
- Industrial-turf gallons per housing unit = 230

Fountain Hills, WPA 57

- The municipal demand supplied by groundwater.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 483
- Industrial-turf gallons per housing unit = 131

RWCD, WPA 60

- The municipal demand supplied by 80% groundwater and 20% surface water.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 398
- Industrial-turf gallons per housing unit = 186

Sun Lakes, WPA 67

- The municipal demand supplied by groundwater.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 553
- Industrial-turf gallons per housing unit = 0

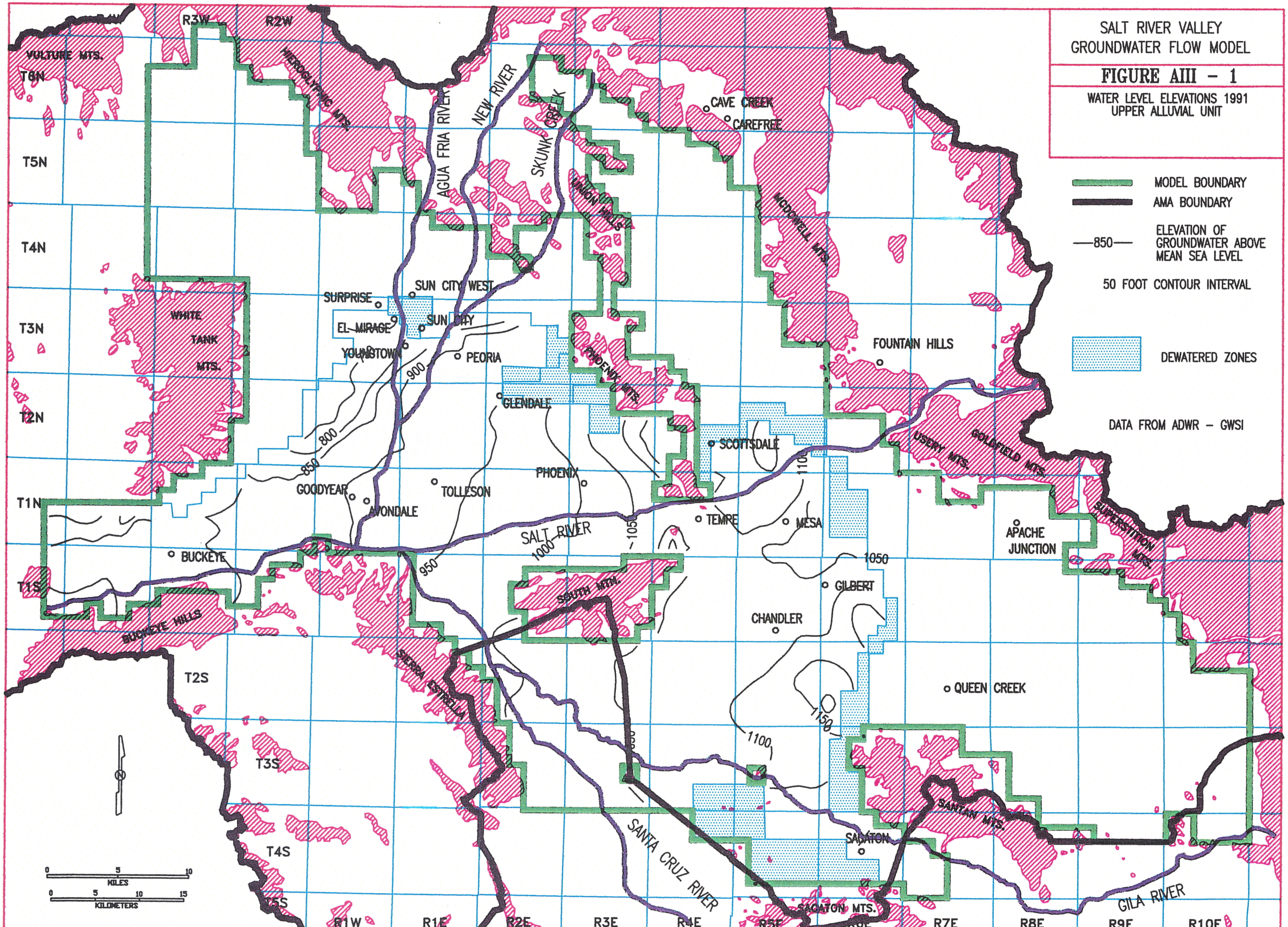
Maricopa East, WPA 70

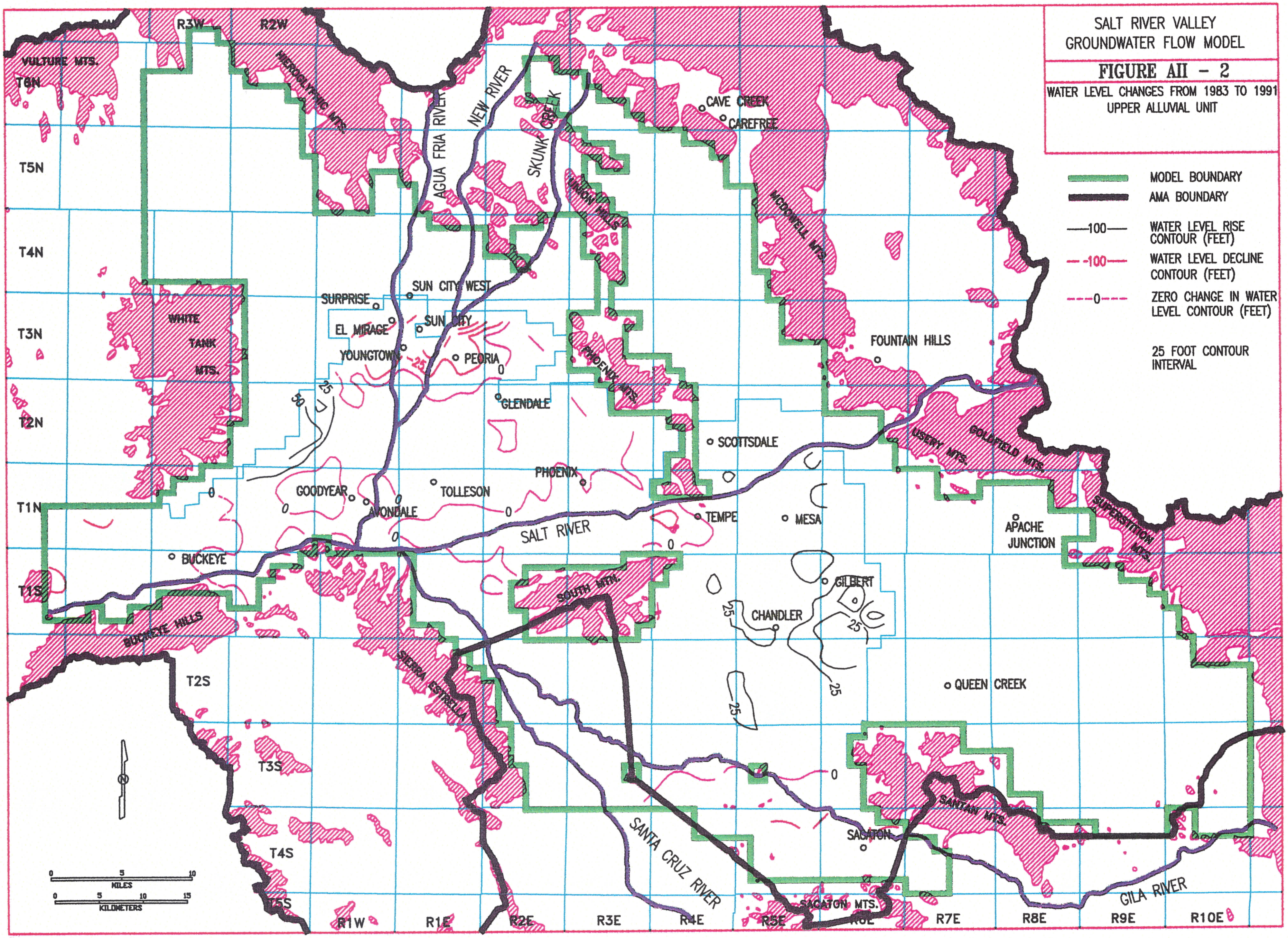
- The municipal demand supplied by groundwater.
- Groundwater demand over the 1991 levels was spread evenly over the WPA.
- Municipal gallons per housing unit = 398
- Industrial-turf gallons per housing unit = 186

APPENDIX III - Upper and Lower Alluvial Groundwater Maps

The hydrogeologic units in the Salt River Valley were subdivided into three units -- the Upper Alluvial Unit (UAU), the Middle Alluvial Unit (MAU), and the Lower Alluvial Unit (LAU). As stated in the report the Middle Alluvial Unit best represents the overall hydrologic conditions, however, there are significant differences between the three layers in some areas. The Upper and Lower Alluvial maps have been included to provide a complete picture of the hydrologic conditions in 1991 and the projected conditions in 2025. The following maps represent the water level elevations, water level change, and the depth to water for the Upper and Lower Alluvial Units using the measured data from 1991 and the result from the CTA scenario for 2025. The areas outside of the blue line in the Upper Alluvial Unit maps represent the dewatered zone as of 1983. Middle Alluvial Unit maps are contained in the main body of this report.

LIST OF FIGURES FOR APPENDIX III

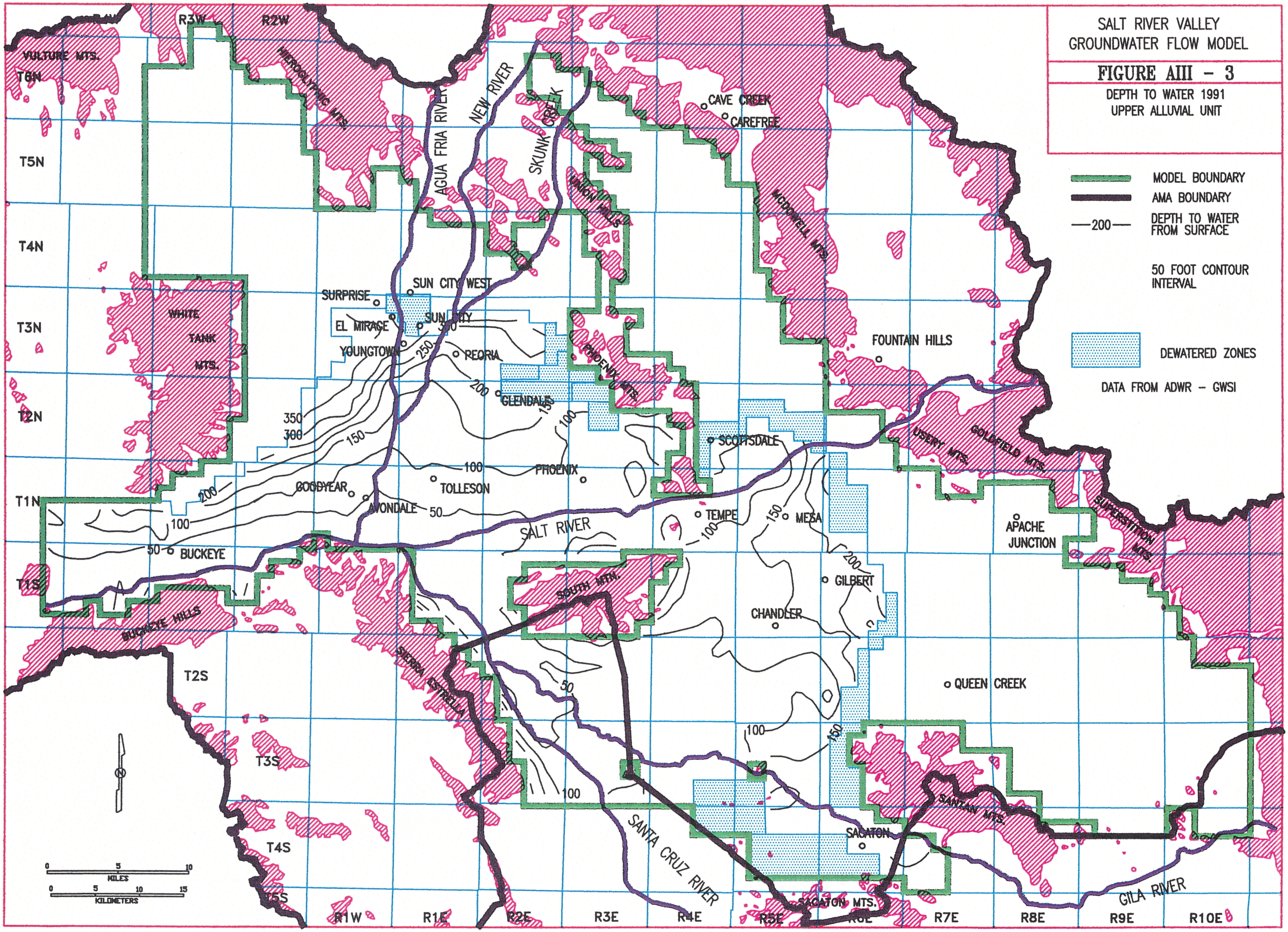

SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE AIII - 1
WATER LEVEL ELEVATIONS 1991
UPPER ALLUVIAL UNIT
MODEL BOUNDARY
AMA BOUNDARY
—850— ELEVATION OF GROUNDWATER ABOVE MEAN SEA LEVEL
50 FOOT CONTOUR INTERVAL
DEWATERED ZONES
DATA FROM ADWR - GWSI
VULTURE MTS.
HIEROGLYPHIC MTS.
WHITE TANK MTS.
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
UNION HILLS
CAVE CREEK
CAREFREE
MCDOWELL MTS.
FOUNTAIN HILLS
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
APACHE JUNCTION
SURPRISE
SUN CITY WEST
SUN CITY
EL MIRAGE
YOUNGTOWN
PEORIA
GLENDALE
PHOENIX MTS.
SCOTTSDALE
PHOENIX
TOLLESON
GOODYEAR
AVONDALE
BUCKEYE
SALT RIVER
TEMPE
MESA
GILBERT
CHANDLER
QUEEN CREEK
SOUTH MTN.
BUCKEYE HILLS
SIERRA ESTRELLA
SANTA CRUZ RIVER
SANTAN MTS.
SACATON
SACATON MTS.
GILA RIVER
800
850
900
950
1000
1050
1100
1150
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S
T4S
T5S
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R7E
R8E
R9E
R10E
0 5 10 MILES
0 5 10 15 KILOMETERS
N


SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE AII - 2
WATER LEVEL CHANGES FROM 1983 TO 1991
UPPER ALLUVIAL UNIT
MODEL BOUNDARY
AMA BOUNDARY
—100— WATER LEVEL RISE CONTOUR (FEET)
-100- WATER LEVEL DECLINE CONTOUR (FEET)
-0- ZERO CHANGE IN WATER LEVEL CONTOUR (FEET)
25 FOOT CONTOUR INTERVAL
VULTURE MTS.
HIEROGLYPHIC MTS.
WHITE TANK MTS.
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
UNION HILLS
CAVE CREEK
CAREFREE
MCDOWELL MTS.
FOUNTAIN HILLS
SURPRISE
SUN CITY WEST
EL MIRAGE
SUN CITY
YOUNGTOWN
PEORIA
GLENDALE
PHOENIX MTS.
SCOTTSDALE
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
GOODYEAR
TOLLESON
AVONDALE
PHOENIX
TEMPE
MESA
APACHE JUNCTION
SALT RIVER
BUCKEYE
BUCKEYE HILLS
SOUTH MTN.
GILBERT
CHANDLER
SIERRA ESTRELLA
QUEEN CREEK
SANTAN MTS.
SACATON
SACATON MTS.
SANTA CRUZ RIVER
GILA RIVER
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R6E
R7E
R8E
R9E
R10E
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S
T4S
T5S
MILES
KILOMETERS

SALT RIVER VALLEY
GROUNDWATER FLOW MODEL

FIGURE AIII – 3

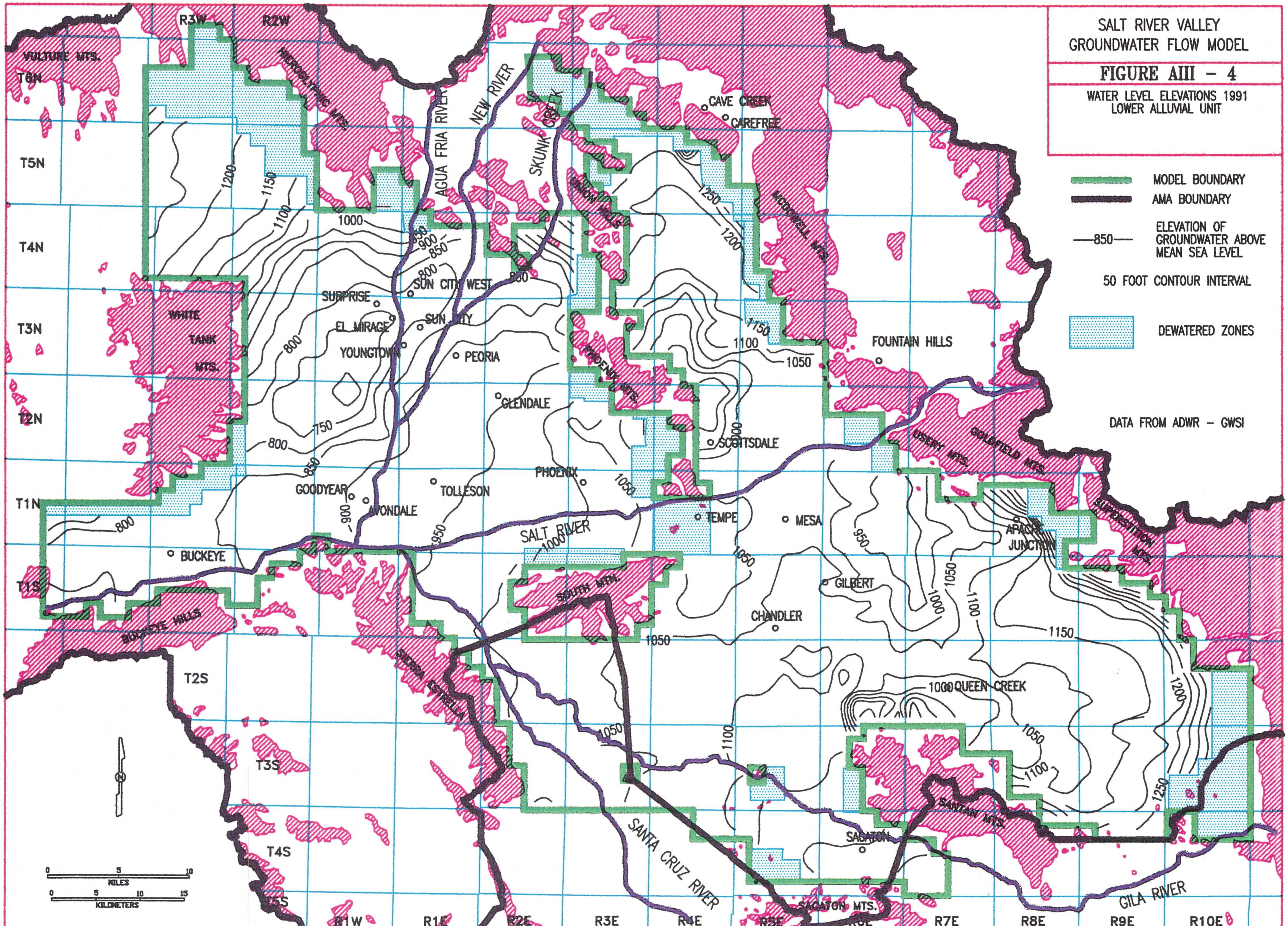
DEPTH TO WATER 1991
UPPER ALLUVIAL UNIT

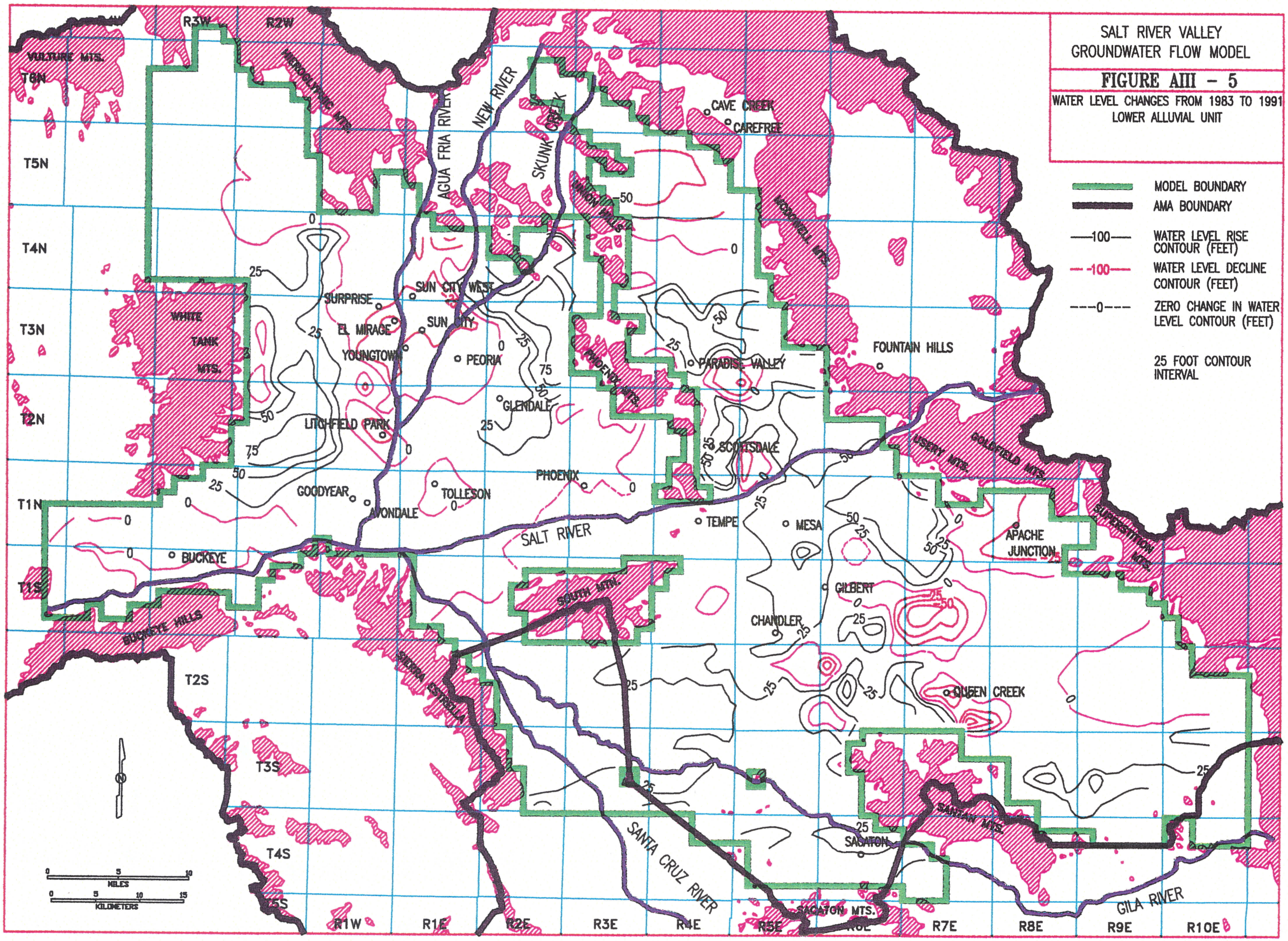


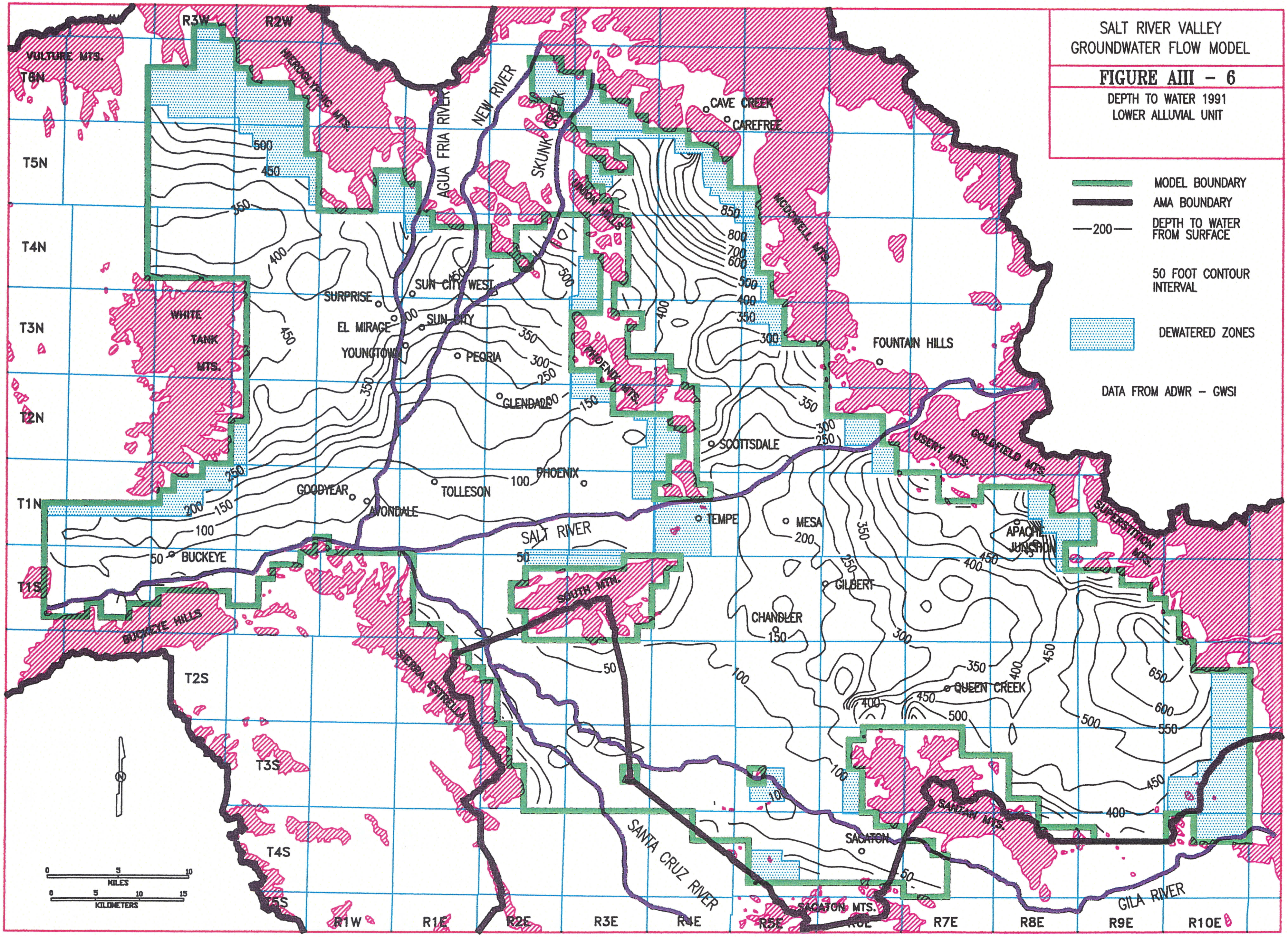
SALT RIVER VALLEY
GROUNDWATER FLOW MODEL

FIGURE AIII - 4

WATER LEVEL ELEVATIONS 1991
LOWER ALLUVIAL UNIT



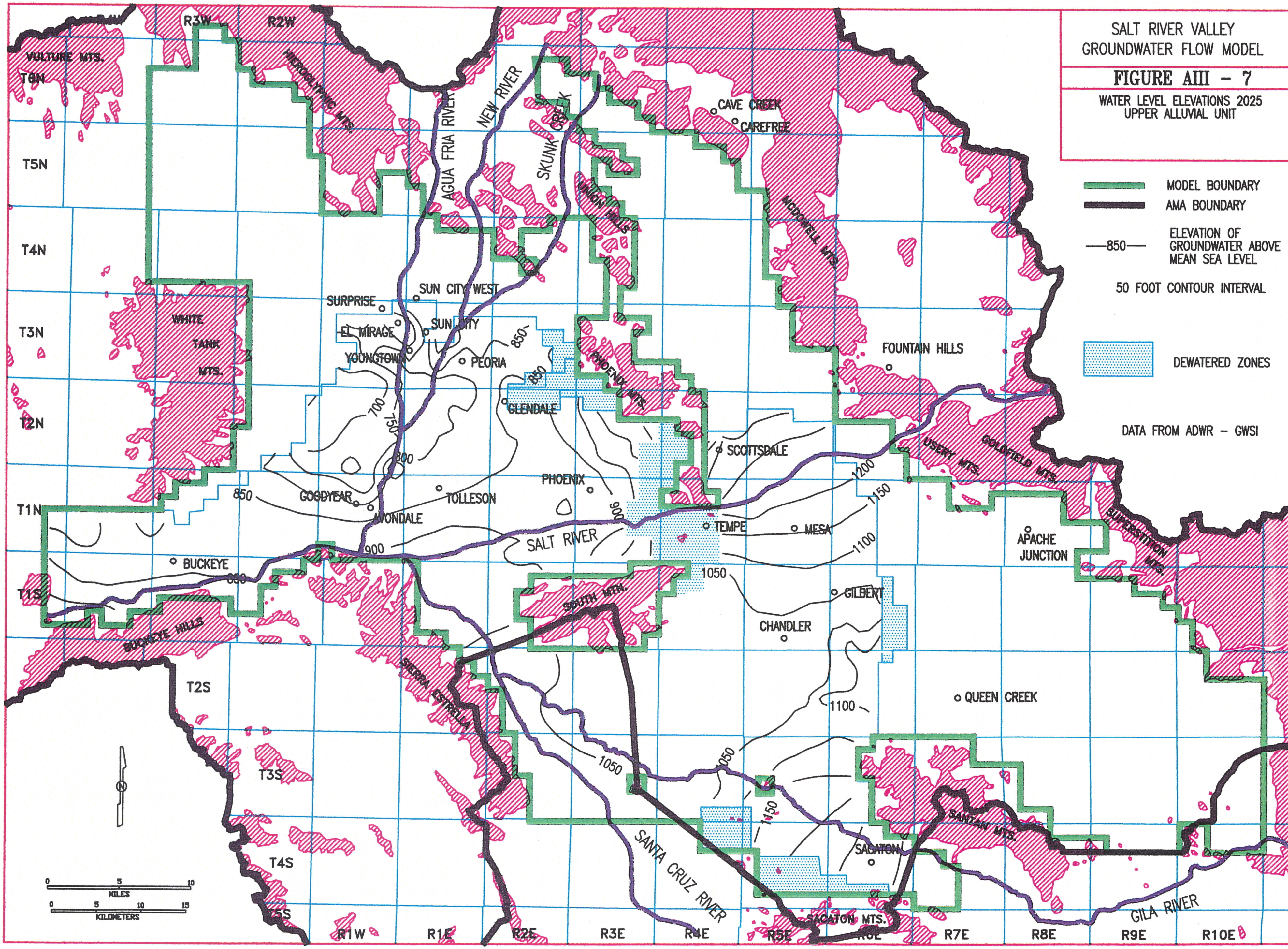

SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE AIII - 5
WATER LEVEL CHANGES FROM 1983 TO 1991
LOWER ALLUVIAL UNIT
MODEL BOUNDARY
AMA BOUNDARY
—100— WATER LEVEL RISE CONTOUR (FEET)
-100- WATER LEVEL DECLINE CONTOUR (FEET)
---0--- ZERO CHANGE IN WATER LEVEL CONTOUR (FEET)
25 FOOT CONTOUR INTERVAL
VULTURE MTS.
HIERROGLYPHIC MTS.
WHITE TANK MTS.
BUCKEYE HILLS
SIERRA ESTRELLA
SOUTH MTN.
PHOENIX MTS.
MCDOWELL MTS.
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
SANTAN MTS.
SACATON MTS.
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
SALT RIVER
SANTA CRUZ RIVER
GILA RIVER
CAVE CREEK
CAREFREE
SURPRISE
EL MIRAGE
YOUNGTOWN
SUN CITY WEST
SUN CITY
PEORIA
GLENDALE
LITCHFIELD PARK
GOODYEAR
AVONDALE
TOLLESON
PHOENIX
BUCKEYE
PARADISE VALLEY
SCOTTSDALE
FOUNTAIN HILLS
TEMPE
MESA
APACHE JUNCTION
GILBERT
CHANDLER
QUEEN CREEK
SACATON
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S
T4S
T5S
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R7E
R8E
R9E
R10E
MILES
KILOMETERS

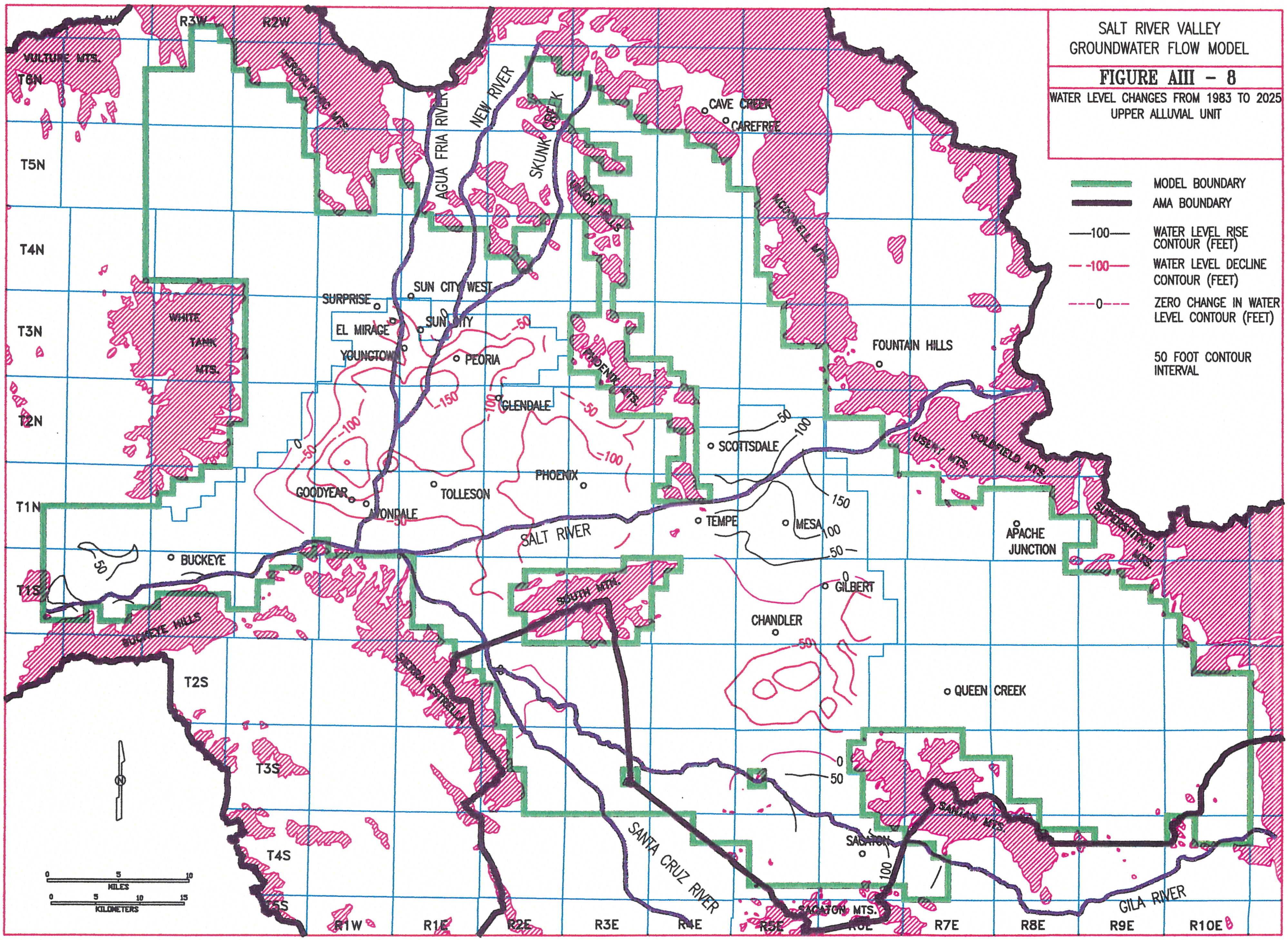

SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE AIII - 6
DEPTH TO WATER 1991
LOWER ALLUVIAL UNIT
MODEL BOUNDARY
AMA BOUNDARY
—200— DEPTH TO WATER FROM SURFACE
50 FOOT CONTOUR INTERVAL
DEWATERED ZONES
DATA FROM ADWR - GWSI
VULTURE MTS.
HIEROGLYPHIC MTS.
WHITE TANK MTS.
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
UNION HILLS
CAVE CREEK
CAREFREE
MCDOWELL MTS.
FOUNTAIN HILLS
PHOENIX MTS.
SURPRISE
EL MIRAGE
SUN CITY WEST
SUN CITY
YOUNGTOWN
PEORIA
GLENDALE
SCOTTSDALE
PHOENIX
TOLLESON
GOODYEAR
AVONDALE
BUCKEYE
TEMPE
MESA
SALT RIVER
SOUTH MTN.
BUCKEYE HILLS
SIERRA ESTRELLA
SANTA CRUZ RIVER
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
APACHE JUNCTION
GILBERT
CHANDLER
QUEEN CREEK
SANTAN MTS.
SACATON
SACATON MTS.
GILA RIVER
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R7E
R8E
R9E
R10E
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S
T4S
MILES
KILOMETERS

SALT RIVER VALLEY GROUNDWATER FLOW MODEL

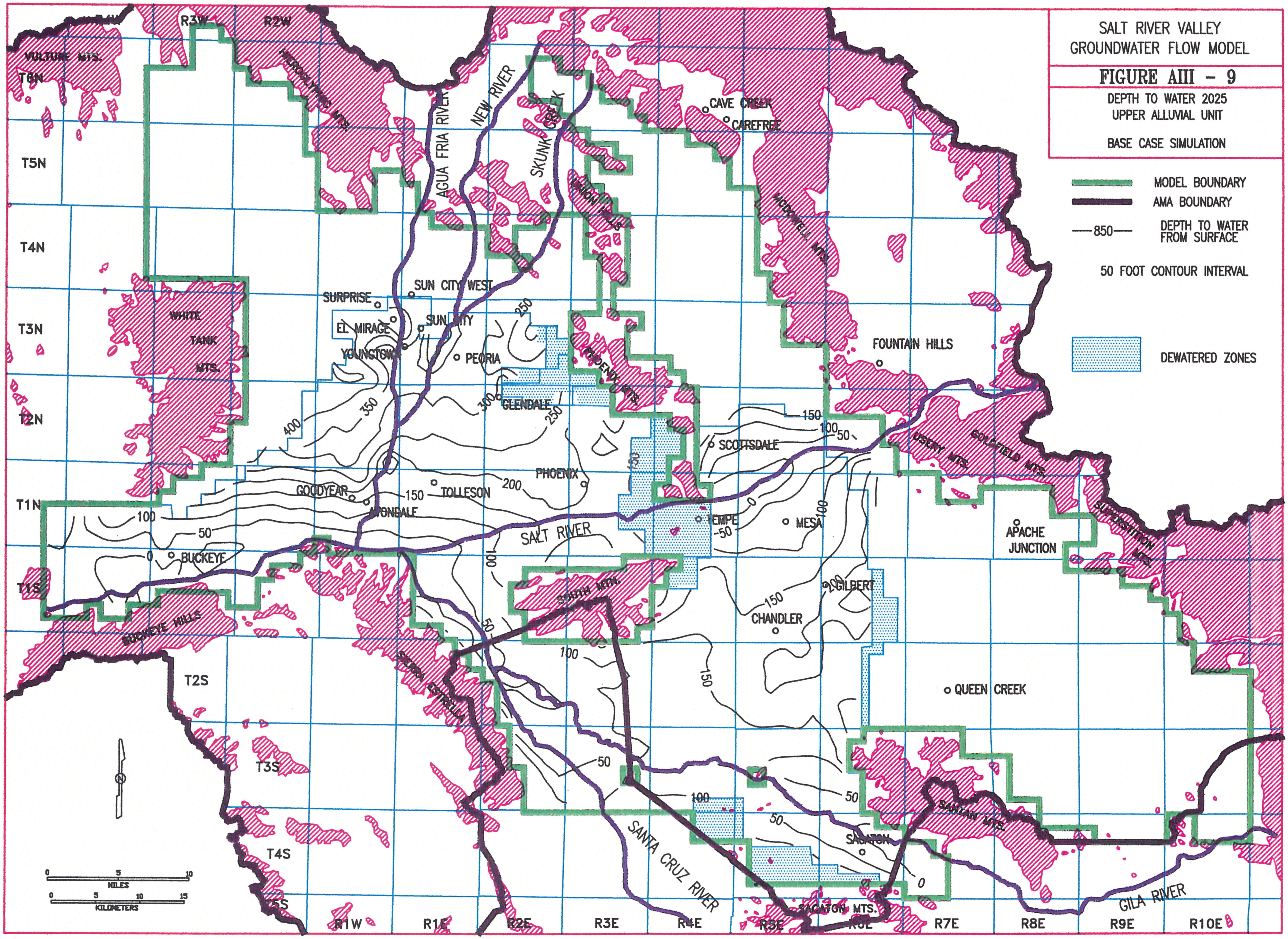
FIGURE AIII - 7

WATER LEVEL ELEVATIONS 2025
UPPER ALLUVIAL UNIT

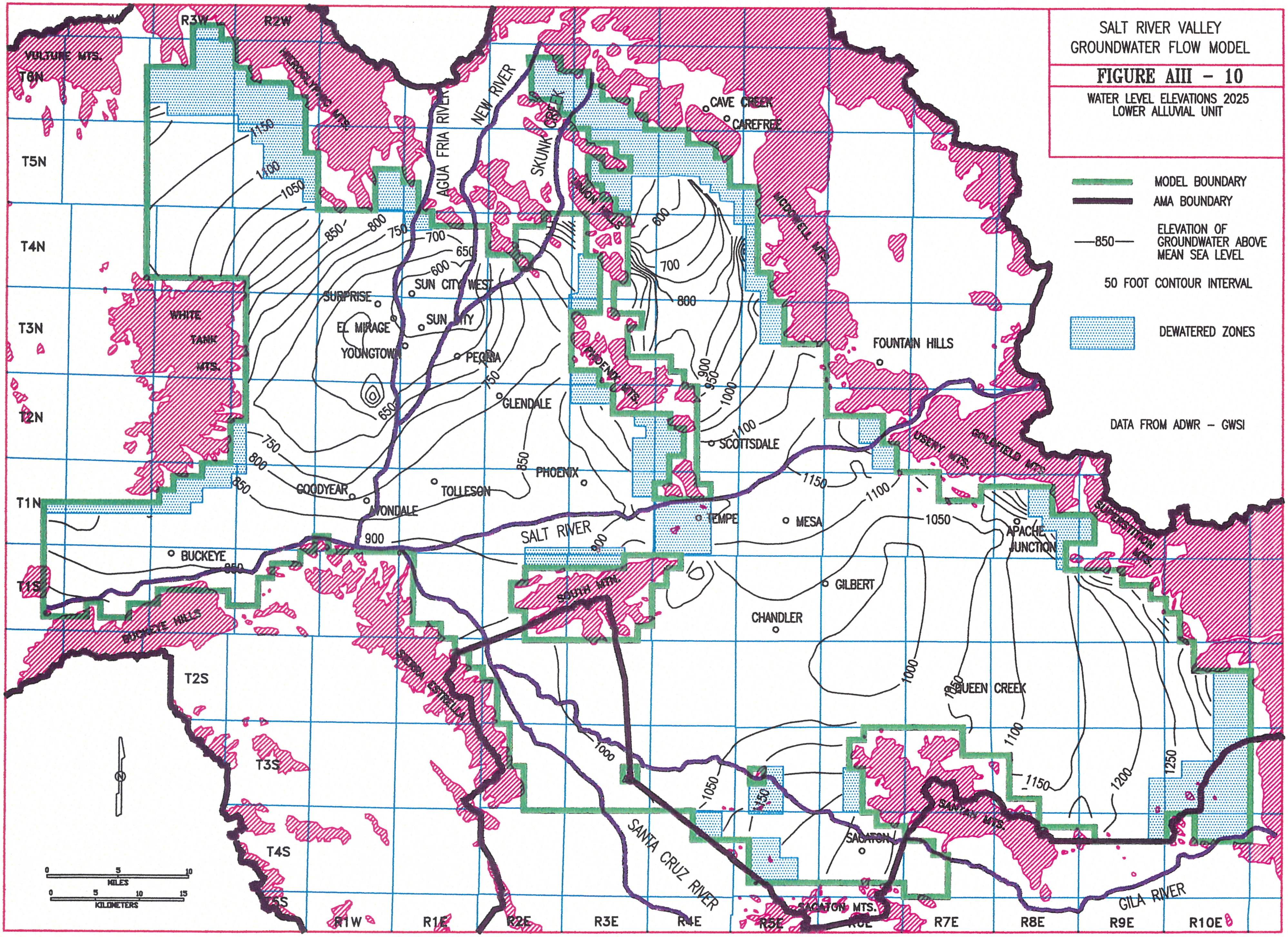


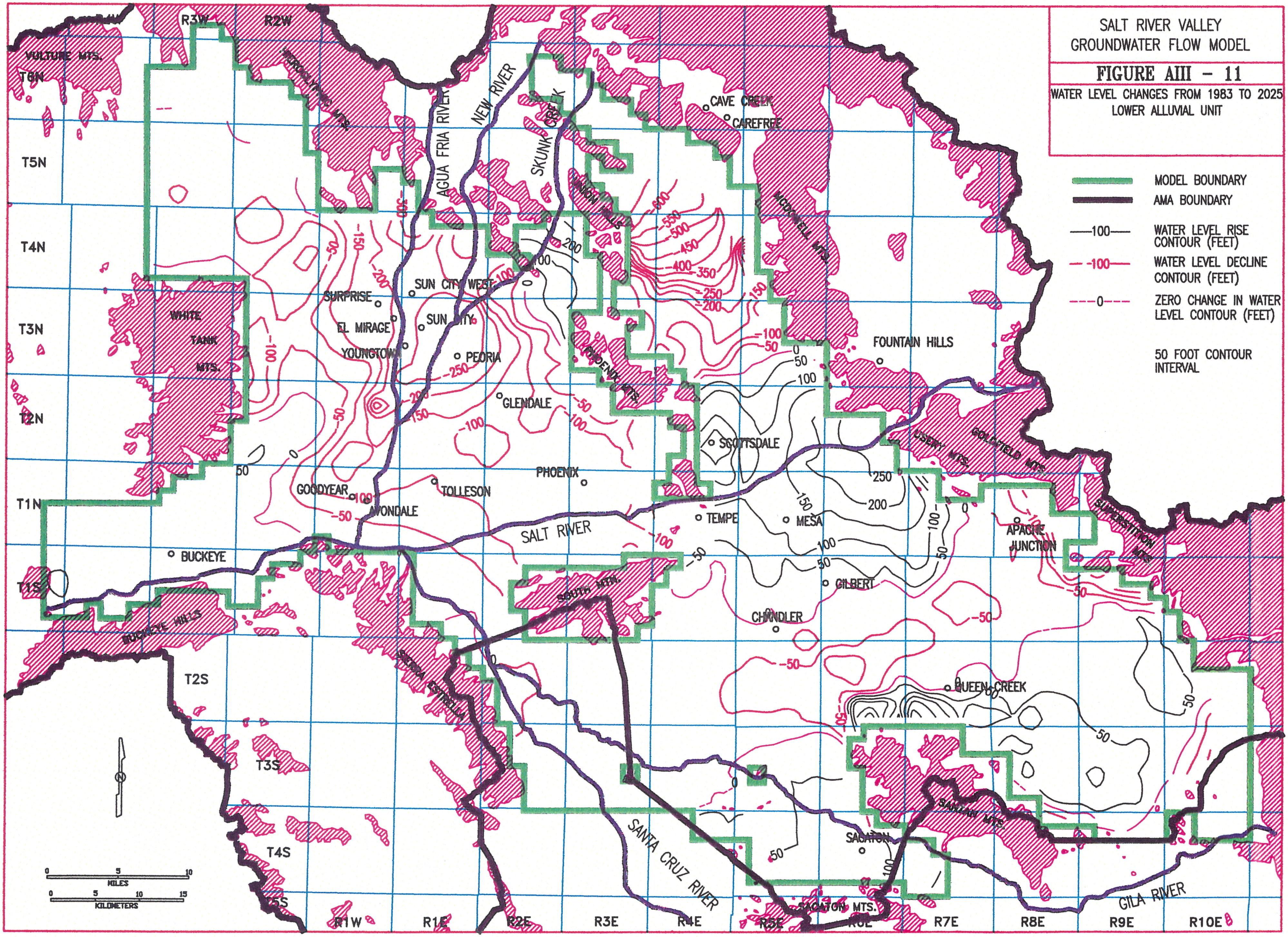


SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE AIII - 8
WATER LEVEL CHANGES FROM 1983 TO 2025
UPPER ALLUVIAL UNIT
MODEL BOUNDARY
AMA BOUNDARY
—100— WATER LEVEL RISE CONTOUR (FEET)
-100- WATER LEVEL DECLINE CONTOUR (FEET)
---0--- ZERO CHANGE IN WATER LEVEL CONTOUR (FEET)
50 FOOT CONTOUR INTERVAL
VULTURE MTS.
WHITE TANK MTS.
CAVE CREEK
CAREFREE
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
SURPRISE
SUN CITY WEST
SUN CITY
EL MIRAGE
YOUNGTOWN
PEORIA
GLENDALE
FOUNTAIN HILLS
SCOTTSDALE
PHOENIX
TOLLESON
GOODYEAR
AVONDALE
TEMPE
MESA
SALT RIVER
APACHE JUNCTION
BUCKEYE
BUCKEYE HILLS
GILBERT
CHANDLER
QUEEN CREEK
SIERRA ESTRELLA
SANTA CRUZ RIVER
SACATON
SACATON MTS.
GILA RIVER
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S
T4S
T5S
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R7E
R8E
R9E
R10E
MILES
KILOMETERS



SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE AIII - 9
DEPTH TO WATER 2025
UPPER ALLUVIAL UNIT
BASE CASE SIMULATION
MODEL BOUNDARY
AMA BOUNDARY
—850— DEPTH TO WATER FROM SURFACE
50 FOOT CONTOUR INTERVAL
DEWATERED ZONES
VULTURE MTS.
WHITE TANK MTS.
BUCKEYE HILLS
SIERRA ESTRELLA
SOUTH MTN.
PHOENIX MTS.
MCDOWELL MTS.
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
SANTAN MTS.
SACATON MTS.
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
SALT RIVER
SANTA CRUZ RIVER
GILA RIVER
CAVE CREEK
CAREFREE
SUN CITY WEST
SURPRISE
SUN CITY
EL MIRAGE
YOUNGTOWN
PEORIA
GLENDALE
PHOENIX
TOLLESON
GOODYEAR
AVONDALE
BUCKEYE
SCOTTSDALE
TEMPE
MESA
FOUNTAIN HILLS
APACHE JUNCTION
GILBERT
CHANDLER
QUEEN CREEK
SACATON
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S
T4S
T5S
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R6E
R7E
R8E
R9E
R10E
MILES
KILOMETERS


SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE AIII - 10
WATER LEVEL ELEVATIONS 2025
LOWER ALLUVIAL UNIT
MODEL BOUNDARY
AMA BOUNDARY
—850— ELEVATION OF GROUNDWATER ABOVE MEAN SEA LEVEL
50 FOOT CONTOUR INTERVAL
DEWATERED ZONES
DATA FROM ADWR - GWSI
VULTURE MTS.
WHITE TANK MTS.
BUCKEYE HILLS
SOUTH MTS.
PHOENIX MTS.
MCDOWELL MTS.
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
SANTAN MTS.
SACATON MTS.
SIERRA ESTRELLA
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
SALT RIVER
SANTA CRUZ RIVER
GILA RIVER
CAVE CREEK
CAREFREE
FOUNTAIN HILLS
SURPRISE
EL MIRAGE
YOUNGTOWN
SUN CITY WEST
SUN CITY
PEORIA
GLENDALE
SCOTTSDALE
PHOENIX
TOLLESON
GOODYEAR
AVONDALE
BUCKEYE
TEMPE
MESA
APACHE JUNCTION
GILBERT
CHANDLER
QUEEN CREEK
SACATON
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S
T4S
T5S
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R6E
R7E
R8E
R9E
R10E
MILES
KILOMETERS
0
5
10
15


SALT RIVER VALLEY
GROUNDWATER FLOW MODEL
FIGURE AIII - 11
WATER LEVEL CHANGES FROM 1983 TO 2025
LOWER ALLUVIAL UNIT
MODEL BOUNDARY
AMA BOUNDARY
—100— WATER LEVEL RISE CONTOUR (FEET)
-100- WATER LEVEL DECLINE CONTOUR (FEET)
---0--- ZERO CHANGE IN WATER LEVEL CONTOUR (FEET)
50 FOOT CONTOUR INTERVAL
VULTURE MTS.
WHITE TANK MTS.
BUCKEYE HILLS
SIERRA ESTRELLA
SOUTH MTN.
PHOENIX MTS.
MCDOWELL MTS.
USERY MTS.
GOLDFIELD MTS.
SUPERSTITION MTS.
SANTAN MTS.
SACATON MTS.
AGUA FRIA RIVER
NEW RIVER
SKUNK CREEK
SALT RIVER
SANTA CRUZ RIVER
GILA RIVER
CAVE CREEK
CAREFREE
SURPRISE
EL MIRAGE
YOUNGTOWN
SUN CITY WEST
SUN CITY
PEORIA
GLENDALE
PHOENIX
SCOTTSDALE
FOUNTAIN HILLS
TEMPE
MESA
GILBERT
CHANDLER
APACHE JUNCTION
QUEEN CREEK
SACATON
GOODYEAR
AVONDALE
TOLLESON
BUCKEYE
T6N
T5N
T4N
T3N
T2N
T1N
T1S
T2S
T3S
T4S
T5S
R3W
R2W
R1W
R1E
R2E
R3E
R4E
R5E
R6E
R7E
R8E
R9E
R10E
MILES
KILOMETERS

SALT RIVER VALLEY
GROUNDWATER FLOW MODEL

FIGURE AIII - 12

DEPTH TO WATER 2025
LOWER ALLUVIAL UNIT

CURRENT TREND SIMULATION